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Class - XIII

ON THE

REVOLUTIONS

OF THE

EARTH'S SURFACE.

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BY

SIR JAMES HALL, BART. PR. R. S. ED. & F. R. S. LOND.

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FROM THE

TRANSACTIONS OF THE ROYAL SOCIETY

OF EDINBURGH.

1813.

Class XII

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PART I.

WE are never more disposed to give credit to a philosophical system, than when we meet with a case of its successful application, unknown to the author, or containing circumstances which he had not taken into account when he formed that system.

The facts brought forward in the following paper, which, according to my view of the subject, clearly indicate the operation of immense torrents, can be accounted for, I think, in a very satisfactory manner, by the Huttonian Theory, and consequently afford some very powerful arguments in support of it.

But such was by no means the view taken of this subject by Dr HUTTON himself, or by Mr PLAYFAIR, who, since his death,

has so ably illustrated and maintained his geological opinions. These gentlemen have expressed themselves, on all occasions, in a manner peculiarly hostile to the employment of such torrents as geological agents, believing that all the phenomena may be traced to the influence of diurnal causes only.

I have no hesitation in declaring my hearty concurrence in what I consider as the essence of the Huttonian Theory; I mean as to all that relates to the influence of internal heat in the formation of our rocks and mountains: But I could never help differing from Dr HUTTON, as to the particular mode in which he conceived our continents to have risen from the bottom of the sea, by a motion so gentle, as to leave no trace of the event, and so as to have had no share in producing the present state of the Earth's surface.

At an early period of life, while I imbibed from the delightful conversation of my worthy friend Dr HUTTON, the spirit of his geological views, I retained my attachment to opinions suggested by M. DE SAUSSURE's observations, which, at a still earlier period, I had acquired in the Alps, and which had been rivetted in my mind by the sight of the phenomena from which they have been inferred. The facts also observed in the Russian empire, and brought forward by Professor PALLAS, relative to the productions of the tropics, which are found upon the banks of the Frozen Sea, appeared to me of sufficient force to justify his belief, that, at some remote period, a torrent of water had swept across the continent of Asia. I have, therefore, been always disposed to combine the doctrines of HUTTON with those professed by the gentlemen just named, relative to marine inundations; and a number of facts which I have observed in this country, will contribute, I hope, to throw some additional light upon this difficult subject.

Before

Before mentioning my own observations, I beg leave to lay before the Society the state in which I found the question. The central ridge of the Alps, of which Mont Blanc is the principal mountain, consists, as is well known, of Granite. Nearly parallel to it, and at a distance of fifty-four miles to the north-west (by Sir GEORGE SHUCKBURGH's measurement) lies the mountainous ridge of Jura, fifty or sixty miles in length, composed entirely of calcareous matter. Between these two ridges are interposed the valley and lake of Geneva, and other valleys and inferior hills. The native place of the granite is confined to the central ridge; but over the surface just described, innumerable detached granitic blocks are very irregularly scattered, which have originated, as we must presume, in that central ridge, and have been transported to their present position by some mechanical power.

Upon the southern side of the Baltic, a multitude of similar blocks are found, also scattered irregularly over a sandy district, of which a particular and detailed account is given in M. DE LUC's Geological Travels, vol. i.

The origin and history of such blocks, which occur in various other places, have given rise to considerable discussion; and the question is inseparably connected with other points of magnitude in geology,—such as the formation of valleys and lakes, and the distribution and arrangement of various beds of clay and gravel, and of all the loose and alluvial assemblages which occur under various forms in all parts of the globe, and constitute its most valuable districts in point of fertility.

M. DE SAUSSURE ascribes the transportation of the granitic blocks on the Alps to the action of an immense torrent of water, or *Debacle*, as he terms it, which at some remote period, flowing over the summit of the Alps, had carried these blocks along with it.

Dr.

Dr HUTTON and Mr PLAYFAIR, as I have already said, deny the necessity of introducing such an agent, since the circumstances, as they conceive, might have been produced by the usual action of rivers. But this simple view seems to be excluded, when we consider both the magnitude and the positions of these blocks. Their size, in some cases, amounts, as in the valley of Monetier upon Saleve, to 1200 cubic feet, and in the case of those on the Coteau de Boisy, to 2250, and even to 10,296 cubic feet, which is the measure of the block called Pierre à Martin.

To move a mass of granite of even fifty or sixty cubic feet, and to carry it a few yards, would require the utmost efforts of the Rhone or the Arve, as they flow near Geneva, in their highest floods, but that such blocks could be conveyed by one of them along its whole course, is contrary, I conceive, to all experience, and still more when we consider that these rivers are divided at their source from beneath the Glaciers into forty or fifty small streams. Yet from the Glaciers, these blocks must have come; and when we take into account the magnitude of some of the granitic masses, it is clear that the task is beyond the power of any river that flows on the surface of the earth; nay, it seems more than water, under any predicament, could accomplish, and more than could be expected from the *Debacle* itself, however extravagant its magnitude may appear: but we shall again return to the subject, and shew in what manner this difficulty may be explained.

These stones do not lie merely in the beds of rivers, but occur all over the country, and on the summits of mountains, where rivers could least be conceived to have flowed; nor are they confined to that side of the country, or to the side of the lake of Geneva which lies next the Alps; for we find them in particular on the face of Jura, which fronts the central ridge

and

and the lake, at an elevation of 2000 feet above the latter. A set of low hills also intervene, which occasionally hide that central ridge from the view; and it is principally where the snowy summits are visible from the face of Jura, by means of some depression in these intervening hills, that we find those travelled masses; as I remember well to have witnessed, at some of the places which SAUSSURE has pointed out, where, in high situations, on the face of Jura, I rode through great assemblages of granitic blocks, three or four feet in diameter.

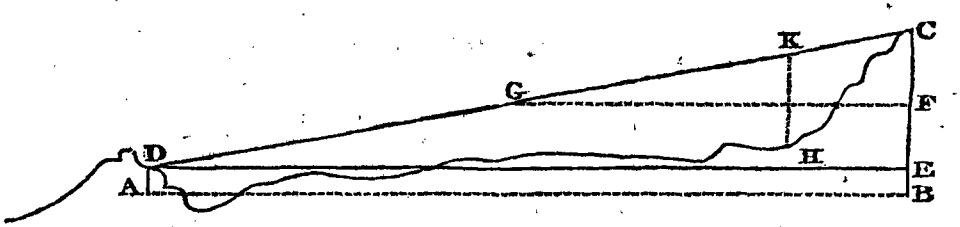
The force of this fact is admitted, but an attempt is made *, even under that admission, to refer the whole to diurnal actions, by supposing, that from the spot where these blocks lie, up to the summit of Mont Blanc, one continued solid plane has ascended, along which, on a declivity computed at one in thirty, these blocks may have been hurried by a stream of water; and that subsequently, in the course of ages, all the intervening mass had been washed away, so as to reduce the country to its present situation. But this hypothesis removes the difficulty of the intervening valleys only; for the transportation in this case would be scarcely less difficult than it would be to Geneva, as matters stand at this day;—and a circumstance occurs, founded upon the observations of Sir GEORGE SHUCKBURGH, which seems entirely to preclude this hypothesis.

According to his measurement and scale, as given in the Philosophical Transactions, vol. lxvii. the height of Mont Blanc is 14,432 feet above the lake, and the distance in a straight line from Jura to Mont Blanc, I find, by his scale, to be nearly fifty-four miles, and 2000 feet is the height at which these granite blocks occur on Jura. The slope, therefore, along which these blocks must have descended, would be nearly that of one in

* *Illustrations*, art. 345, page 385.

in twenty-three. But without inquiring whether or not this declivity would be sufficient for the purpose, it is of consequence to attend to another circumstance pointed out in these measurements. The line above which snow lies perpetually, during all summer, is there noted, and lies by the scale at 7500 feet perpendicular below the summit of Mont Blanc. It is easy, then, to calculate to what horizontal distance from the centre of the ridge, this limit of perpetual snow would extend, and we thus find it to be 32 miles *. But SAUSSURE has found the junction of the granite with the surrounding strata at the *Buet*, and by the same scale, I find the distance of this mountain from Mont Blanc is about 10 miles. It is obvious, then, that in the supposed situation of the Alps, in which the granitic

* Let AD be Jura, and BC Mont-Blanc. Let D be the place on Jura where the blocks lie; the line DC will be the outline of the supposed surface. Let AB be drawn horizontally at the level of the surface of the lake, and DE at a level 2000 feet higher, meeting BC in E. We have then AB = DE = 54 miles = 285120 feet; and CE = CB — EB = 14432 — 2000 = 12432 feet. The measure of this declivity along CD may therefore be easily obtained. Thus, CE : ED : : 12432 feet : 285120 : : 1 : 22.9, nearly one in twenty-three. Mr PLAYFAIR states it at one in thirty; but he has reckoned to the summit of Jura; whereas the blocks under consideration lie at some distance below that summit.



Let CF be equal to 7500 feet, and let FG be drawn horizontally; then G will be the lowest point of perpetual snow upon the supposed surface. The horizontal distance of G from the centre will thus be obtained, CE : CF : : ED : FG, or 12432 : 7500 : : 54 miles : 32½ miles. Let H be the extreme point of the granitic mass at the Buet, and let HK be drawn vertically; the point K will denote the limit of the granite upon the supposed surface.

nitic mass could not be conceived to extend farther than it now does from the middle, that the whole granitic surface must not only have been buried in everlasting snow, but that the extent of this snow must have been three times that of the granite. Now there is every reason to suppose, since the temperature diminishes as the height increases, that within this upper third, the temperature has never, in the hottest day in summer, reached so high as 32°; that is to say, that water has never there existed in a liquid form. We cannot, then, conceive any block, however small, to have been conveyed from thence by means of water, acting by the usual diurnal laws.

M. DE LUC admits the reality of M. DE SAUSSURE's debacle, and accounts for it in the same manner; but he does not ascribe to it, either in Germany or in the Alps, the transportation of the granitic blocks, the presence of which he accounts for very differently. He supposes that these blocks have nowhere migrated along the surface, but have been ejected from below, at the places where they now lie. This ejection he produces by a very extraordinary hypothesis *, founded entirely on gratuitous suppositions, and which affords no plausible solution of the difficulty, by which we might be tempted to adopt it.

M. DE LUC mentions a theory formed by Mr WREDE, a Professor of Berlin, to account for the same blocks. He embraces a belief which seems to have been in considerable favour, that the level of the Baltic Sea has been sinking for ages past, and he extends his belief of the same change taking place in the

 whole

* He supposes, that below the firm crust of the earth, then lying horizontally at the bottom of the sea, a set of caverns once existed, filled with peculiar elastic fluids. That at a certain period, this crust breaking to pieces, fell with great violence into these caverns, and drove out the elastic fluids contained in them with such impetuosity, that the blocks of granite under consideration, which then constituted portions of the lower part of the crust, were forced upwards into the air, and fell back into their present position.

whole of the North Sea. His idea is, that a change has been gradually going forward in the position of the centre of gravity of the earth, which has been moving to the southward, and that an equivalent rise is experienced in the southern hemisphere. That when the North Sea stood at its highest level, these granitic blocks had been transported across the Baltic, by means of the winds, on floats of ice, and settling in their present places, had been left by the retiring waters.

M. DE LUC, in a very satisfactory manner, in my opinion, refutes one essential part of this system, by shewing, from the form of the new lands, and from other circumstances, that no change in level whatever has taken place on the surface of that sea for many ages back, and, indeed, ever since the surrounding country has possessed its present form. As to the other part of his system, which relates to the transportation of these blocks by means of ice, we shall soon have occasion to resume its consideration.

Besides the consequences resulting from these particular phenomena, there are other material branches of Dr HUTTON's theory connected with the same views, which in my opinion require to be carefully revised. The theory which he has advanced respecting the formation of valleys, by mere diurnal actions, appears to me liable to great objections, and I cannot help agreeing with M. DE LUC, in much that he has urged against Mr PLAYFAIR on this point. I also concur with my friend Sir GEORGE MACKENZIE, in some general views, suggested to him by the aspect of certain rocks in Iceland, and in rejecting the slow operations of the atmosphere (*Travels in Iceland*, p. 39.)

The difficulty is peculiarly great where a lake occupies the bottom of the valley, and is very conspicuous in the case of the lake of Geneva lately mentioned. For, granting all that has been

been advanced in support of the diurnal formation of the valley in which this lake lies, granting that it has been excavated by the diurnal actions, since these granitic blocks were deposited upon Mount Jura; it still remains to be explained, how the lake of Geneva itself was formed, the depth of which amounts in some places (SAUSSURE, art. 44.) to 950 feet. Now, as has very fairly been stated, this lake is constantly receiving all the spoils of the district which lies above it, called the Vallais, yet delivers nothing at Geneva, situated below it, but pure water. It is evident, then, that every known diurnal action tends to fill up this lake, and none to excavate it. This is therefore admitted by Mr PLAYFAIR, to be a case "in "which hypothetical reasonings are warranted by the strictest "rules of philosophical investigation, and where we must "therefore have recourse to an agent that is invisible." *Illustrations of the Huttonian Theory*, p. 366.

This acknowledged difficulty seems calculated to entitle the following speculations to a patient hearing from this gentleman; and he has already, in another part of the same work, expressed himself with regard to them, and other kindred opinions, in a manner highly encouraging to discussion, and which affords one of the most striking examples of candour that has ever occurred.

"These arguments," Mr PLAYFAIR says, (referring to those he had just been stating) art. 367. page 412. "appear to me "conclusive against the necessity of supposing the action of "sudden and irregular causes on the surface of the earth. In "this, however, perhaps I am deceived, neither PALLAS nor "SAUSSURE, nor DOLOMIEU, nor any author who has espoused "the hypothesis of such causes, has explained his notions "with any precision; on the contrary, they have all spoken "with such reserve and mystery, as seems to betray the weak-

" ness, but may have concealed the strength of their cause. I " have, therefore, been combating an enemy that was in some " respects unknown, and I may have supposed him dislodged, " only because I could not find his strong holds."

The charge of obscurity here brought forward, is very applicable to the diluvian system of SAUSSURE and DE LUC, in what regards the origin of the torrent, or the disposal of the water after it had overwhelmed the land. The same charge seems not, however, to apply to the suggestion of Professor PALLAS, who, in an early work, entitled, *Observations sur la Formation des Montagnes*, first published in 1777, has very explicitly ascribed the inundation by which he conceives the continent of Asia to have been overwhelmed, to the action of volcanoes rising in the Indian Sea, and forming the Moluccas, the Philippines, and other islands, known or supposed to be volcanic.

It must be admitted, that such an event may occasionally have happened. But the occurrence of similar catastrophes may be inferred in a manner still more general and unequivocal, from those Plutonic * revolutions the reality of which has been established by Dr HUTTON's observations. According to his system, all our strata once lay at the bottom of the sea, and have been raised into their present situation by the subterranean and submarine exertions of heat, similar to that which appears externally in the volcanoes. And the angular fractures exhibited by these beds on many occasions, prove that this elevation was performed in such cases when the mass was in a hard state. It is obvious, then, that the same principle which I lately attempted to apply (page 87. of this volume) to the volcanic phenomena, as exhibited in the *Atrio del Cavallo*, will apply to those Plutonic revolutions; and we are authorised

* I need scarcely say, that by the term *Plutonic*, I mean to characterize that geological system in which the principal agent is heat acting under *Compression*.

sed on these principles to expect, that the liquid substances of basalt and of granite, in their progress through the rents of our strata, have been exposed to congelation, like the lava in the rents of Mount Vesuvius; that their progress has been arrested, and the protruding energy accumulated in a similar manner, till it acquired sufficient power to break through that obstacle, or through some other opposed to it; and it is manifest, however gradual and uniform the propelling force may have been previous to its accumulation, that the ultimate laceration must have been performed, by a sudden and violent motion, producing an earthquake at the surface, and thus affording a more extensive and more satisfactory solution of that tremendous Phænomenon that is furnished by the steam of Mr MITCHELL; though I am ready to admit, that in the volcanic actions, the production and condensation of steam, on many occasions, has produced very powerful effects. In the Plutonic regions, as the restraining mass was beyond all comparison stronger, and thicker and heavier, than in the most violent volcanic action, it must have exerted a power of resistance greater in the same proportion; consequently, the time of that constraint must have been of incomparably longer duration, and the violence of the shock, when the fracture did take place, though no less sudden, must have been incomparably more powerful.

Thus, as Vesuvius, in the course of the middle ages, was once at rest during several centuries, we have reason to presume that the Plutonic action, after being suspended for several thousand years *, should rush forward with a degree of violence proportioned

* This observation meets an objection urged against Dr HUTTON by M. DE BREISLAC, a gentleman to whom I feel indebted for the handsome manner in which he has mentioned the result of my experiments, and who, on most occasions, has treated our views with peculiar fairness, but who seems in this important

portioned to the time of its previous constraint, and capable of fulfilling all the conditions of SAUSSURE's *debacle*, or the wave of PALLAS; and the existence of these tremendous events is thus indicated *à priori* by the Huttonian principles.

I shall now consider, whether such traces have not been actually left by these waves, as to place the reality of their existence beyond all doubt. We have already alluded to some of these, and shall have occasion to mention some others; but in a case of this sort, no historical, nor even traditional authority need be expected; for though no limit could well be assigned to the magnitude which such a wave might actually reach, there is a decided limit to the magnitude of one that could be recorded; since, by exterminating all witnesses, every wave beyond a certain size would infallibly be the cause of its own oblivion. Those of a moderate extent are most likely to have been recorded by man, having sufficient power to produce the most awful impressions, and yet sparing a sufficient number of witnesses to transmit the event to future generations.

In our attempts to elucidate this subject, we shall refer, in the first place, to specimens of this tremendous phenomenon in still lower stages of its power, since they alone have been recorded in an authentic and intelligible form, I mean, by referring to those agitations of the sea which have accompanied most of the great Earthquakes in our own times, as we learn from the following regular statements.

In

portant article to have altogether misapprehended the system proposed. In his late work, (*Introduction à la Geologie, tr. Fr.* p. 115.) he urges as subversive of Dr HUTTON's views, some thermometrical observations in which the bottom of the sea was found to be as cold as its surface. To urge this as an objection, implies that the heat employed in this system is supposed to be for ever, and everywhere, acting upon the sand of the sea; whereas it is well known that Dr HUTTON conceived that the subterranean heat, as well as that of the volcanoes, was subject to short fits of activity, with ages of intermission.

In the *Philosophical Transactions*, vol. XLIX. p. 424. we have an account of the earthquake at Cadiz, by Mr B. BEWICKE, merchant there, 1st November 1755, in which it is said, "an hour after" (the first shock) "looking out to sea, we saw a "wave coming, at eight miles distance, which was at least six-"ty feet higher than common. Every body began to tremble; "the centinels left their posts, as well they did; it came "against the west part of the town, which is very rocky; the "rocks abated a great deal of its force; at last it came upon "the walls, and beat in the breast-work, and carried pieces of "eight or ten tons weight, forty or fifty yards from the walls," &c.

We have another account of the same by Don ANTONIO DE ULLOA, *Phil. Trans.* vol. XLIX. p. 427. who describes the wave as having returned five times after the first *. And similar facts are stated of other scenes of this sort.

One circumstance in addition to those mentioned, which has accompanied all these great events, and which seems at first sight to contradict our explanation of them is, that in all the agitations of the water, the first event has been a retreat of the sea.

Mr

* He says, "the inhabitants had scarcely begun to recover from their first "terror, when they saw themselves plunged into new alarms; at ten minutes "past eleven, they saw, rolling towards the city, a tide of the sea, which passed "over the parapet of sixty feet, above the ordinary level of the water; at thirty "minutes past eleven came a second tide, and these two were followed by four "others of the same kind, at fifty minutes past eleven; at twelve o'clock, thirty "minutes; one o'clock, ten minutes; one o'clock, fifty minutes. The tides "continued, with some intervals, till the evening, but lessening. They have "ruined one hundred toises of the rampart, part of which, of three toises length, "and of their whole thickness, were carried by the torrent fifty paces." It is remarkable, that in these six waves, the two first intervals of time are exactly of twenty minutes each, and the three others of forty. It is probable, that they have all resulted from one great impulse.

Mr Mitchell says, *Philosophical Transactions*, vol. xli. p. 566. 611. speaking of the earthquake at Lisbon in 1755, "the bar (at the mouth of the Tagus) was seen dry "from shore to shore, then suddenly the sea, like a "mountain, came rolling in. This phenomenon accom- "panied the same earthquake at the island of Madeira, "where we are told, that at the city of Funchal, the "sea, which was quite calm, was observed to retire sud- "denly some paces, then rising with a great swell, without the "least noise, and as suddenly advancing, entered the city *." He further states, in the same page, that "in the northern "part of the island the inundation was more violent, the sea "retiring there above one hundred paces at first, and sudden- "ly returning, overflowed the shore, forcing open doors," &c. Again, in page 466. he says, "The great earthquake that de- "stroyed Lima and Callao in 1746, seems also to have come "from the sea; for several of the ports on the coast were "overwhelmed by a great wave, which did not arrive till four "or five minutes after the earthquake began, and which was "preceded by a retreat of the waters, as well as that at Lis- "bon."

Looking into the original account of these calamities in Don Antonio de Ulloa's Travels into South America, French edition, vol. i. p. 467. I find that he mentions two events of this sort, which took place at Callao; one in 1687, in which the sea first retreated, and then returned with such force as to overwhelm Callao and other places. And again in 1746, when, in the course of twenty-four hours, two hundred shocks were felt: on this occasion, the sea retiring as it had done formerly, on similar occasions, returned furiously, and overwhelmed Callao

* *Philosophical Transactions*, vol. xlix. p. 433. The retreat is here said to have begun an hour and a half after the shock.

lao so completely, that nothing remained of the whole town but a remnant of Fort Santa Cruz. Out of twenty-three vessels at anchor in the harbour, nineteen were sunk, and the four others, one of which was a frigate, were carried to a great distance on shore, and left on dry land. At Callao, out of four thousand inhabitants, only two hundred were saved.

Mr MITCHELL endeavours to account for this, by his favourite doctrine of steam, according to which he conceives, that the strata at the bottom of the sea have been raised as a roof; he then continues, (p. 613.) "now while the roof is raising, the "waters of the ocean, over it, retreat, and flow from thence "every way; this, however, being brought about slowly, they "will have time to retreat so gently, as to occason no great "disturbance; but as some part of the roof falls in, the "cold water contained in its fissures mixing with the steam, "will immediately produce a vacuum, in the same manner as "the water injected into the cylinder of a steam-engine, and "the earth subsiding, and leaving a hollow place above, the "waters will flow every way towards it, and cause a retreat of "the sea on all the shores round about." But the gradual elevation of the roof, keeping tight all the while, which is here assumed as the steam was collecting, can by no means be admitted; since, as we have shewn, a mass such as this, when forced upwards, would have yielded suddenly.

This phenomenon, however, along with all the rest mentioned, may, I conceive, be traced as consequences of the simple, but rapid, elevation of the bottom, which we have ascribed to the forcible introduction from below of stone in liquid fusion. Water being almost incompressible, or elastic in an extreme degree, it is obvious, that an elevation of that portion of the fluid which lay immediately upon the part of the bottom raised, would take place almost simultaneously. This

elevation would of course be the greatest in the middle, the quantity of matter in the vertical line being the least; but there is no doubt that an action of the same kind, diminishing in a high ratio, as the distance from the centre increased, would be extended all round; the surface of the fluid being thrown into the form of some species of conchoid, produced by the revolution round the vertical axis $c\,b$ of the line $d\,c\,e$, (Plate VI. fig. 1.) the highest point of which is at c, with a contrary flexure at f and h, and going off beyond these points, in such a manner as to have the original level surface of the water $d\,b\,c$ for an asymptote. This conchoidal elevation, produced in the first moment, being just equal in bulk to the quantity of water displaced by the solid mass $(a\,a)$ elevated at the bottom.

If this mass stopped suddenly, as would naturally happen, when, in consequence of the rupture, the protruding liquid stone has found a vent; it is evident, that every part of the water put in motion during the first moment, would tend, according to the first law of motion, still to continue moving during the next and following moments; but this tendency could not be everywhere effectual; because, if all the water that rose in the first moment were to rise also in the second, a vacuum would be the consequence. In the second moment, then, a struggle must take place between the different portions of the fluid; the middle portion, which had acquired the greatest velocity, would continue to flow upwards, and its place not being supplied from below, as, during the first moment, a suction would be exerted downwards, upon all the surrounding fluid. The consequence must be, that the rise which each particle would have performed by its separate momentum, during this second moment, would be counteracted by the pressure of the atmosphere, and entirely done away at a certain distance from the centre, as at f and h, fig. 2.; beyond that limit the water would sink

sink below the medium level, as at *k* and *i*. An annular depression would thus be produced, surrounding the central elevation, vertical sections of which are exhibited by *d k f* and *h i e*; that depression below the medium level being exactly equal in bulk to the additional elevation at the centre, occasioned by the momentum, the vertical section of which is *f g h c*. The middle elevation, and the annular depression, would continue to increase during a period, and to an amount regulated by that class of laws, which determines the magnitude and duration of waves, as relative to the wind which produces them; and the water at the end of that period would be thrown into the position denoted by the dotted line in fig. 2, and by the single continued line in fig. 3., indicated in both figures by the letters *d k f g h i e*.

During a third period, the water flowing from without the annular depression, to fill it up, a wave of depression would be propagated outwards in all directions, and would visibly reach to places where the elevation produced by the direct impulse in the first moment, had not been at all perceptible, in consequence of their distance from the centre. It is owing to this cause, I am convinced, that the catastrophes at Lisbon, at Cadiz, at Madeira, and at Lima, in so far as the position of the surface of the sea was concerned, were all first announced by a retreat of the sea, as shewn at *m*, in fig. 4.

During another successive period, the undulatory motion continuing, the wave of elevation would advance towards the shore at *m*, and being met by the retiring water, would produce the curling form called the breaking of a wave, as shewn at *m* in figure 5. At that instant the calamitous effects described in all the great earthquakes, as resulting from the sea, have been produced.

I have made a few experiments lately with explosions of some pounds of gunpowder under water, in order to try the effect of sudden impulse. In every case, a very manifest heave of the surface was produced at the instant of the explosion; and at that same instant, a very smart percussion was felt. This was always followed in two or three seconds by a distinct and separate agitation of the water, occasioned by the rising of the permanently elastic gases produced in the explosion. The form given to the wave in fig. 1. has been sketched from the recollection of that first momentary impulse.

We have thus a theory of those waves which seem almost invariably to have accompanied the great earthquakes; supposing these to have been occasioned by submarine elevations, and to form an intermediate step between the volcanic eruptions, and the truly Plutonic operations by which our continents have been elevated.

But, to return to the alpine scenes with which we set out: If the phenomena on the banks of the lake of Geneva, to which we have alluded, were really occasioned by a torrent of water, its magnitude must have been such as to leave few vestiges of the human race, in Europe at least, to record the circumstance; and we can only expect to find proofs of its reality in geological facts. The events of Lisbon and of Callao, though on a scale comparatively diminutive, help to lead our imagination to the conception of this colossal disaster. It may still, however, be alleged, as I have already hinted, that it would be impossible for water of any depth whatever, or moving with any velocity, to carry blocks of such magnitude to such situations; and the consideration is of so great importance, that I am induced, in attempting to unite the ideas of Saussure with those of Hutton, to retain part of the system proposed

proposed by M. WREDE, in so far as to consider the granitic blocks as having been made to float, by means of a mass of ice attached to each.

A circumstance happened lately in this country which tends to encourage that idea. Upon the coast of the Murray Frith, a large block of stone, four or five feet in diameter, lying within high-water mark, and well known as having served to denote the boundary between two estates, was, during a stormy night in winter, transported to the distance of ninety yards, and the persons upon the spot were convinced, that this migration was performed by means of a large cake of ice, formed round the stone, and attached to it; and that the whole had been lifted and carried forward by the rising tide. The course of this stone was marked upon the sand below, by a deep and broad furrow, which remained visible for a long time afterwards, as I have been informed by several members of this Society, who saw it after an interval of more than a year.

By supposing that an agent of this sort acted in concert with our diluvian wave, the difficulty with regard to the transportation of the granitic blocks, seems to be in a great measure removed; and this explanation happens to be peculiarly applicable to the case in point; the native place of these blocks being covered profusely with ice, in the state best calculated for fulfilling the office here assgned to it. M. DE SAUSSURE has given the following clear account of the formation of the Glaciers. In any region whose temperature is such that the heat of summer is not sufficiently powerful to melt all the snow of winter, the remaining snow, which, by partial thawing, and subsequent freezing, is turned into ice, must accumulate year after year to an unbounded degree, so that the mass must become at last so lofty, as to be unable to bear its own weight, and must produce a motion downwards, which will be greatly assisted

assisted by fractures, and by the sliding of the ice upon the ground. In this manner the glaciers are produced, which consist of an assemblage of great blocks of ice, each as big as a house, which, sliding and rolling upon each other during summer, make their way from the high frozen valleys where they were formed, through narrow glens, into the rich and warm vales below, in which they remain a considerable time, presenting a curious spectacle among the meadows and woods, some of which they overtop. These masses, however, melt at last, in this new situation, and leave vast assemblages of stones, which had been attached to them, forming a ridge called the *Marene* of the Glacier.

It is obvious, then, that a wave washing over these high alpine valleys in summer, would float and carry off all the ice in the glaciers, and accumulated in the higher valleys, and, along with the ice, all the blocks of stone imbedded in it, or attached to it in any way. The stream, with this load, would find its way through every opening, and would in a particular manner flow through those depressions, which at this day, as we have said, afford a view of the snowy summit of *Mont Blanc*, from certain places on the face of Jura where these blocks abound.

The enormous masses already mentioned, which are found near Geneva, and at the Coteau de Boisy, may now be accounted for; and the same system will apply also to the blocks upon the Baltic, which may have been brought to their present place, not by a permanent and steady position of the ocean, varying by slow degrees, as has been alleged by M. Wrede, but by a sudden diluvian wave washing over some district, situated either at a sufficiently high level, or near enough to the pole to be the seat of glaciers. I am not at present acquainted with any facts by which the native place of these blocks

blocks can be traced; but I trust we shall not long remain in that state of uncertainty, since there are means by which that point will be found of very easy decision, as I shall endeavour to shew in a subsequent part of this paper, by examples in the neighbourhood of Edinburgh.

It is well known, that granite is found native in Sweden; so these blocks may have been carried across the Baltic, as those of Mont Blanc have crossed the valley of Geneva. It is possible also, that they may have been transported by the help of ice from the Alps across Germany, by the very same torrent we have been considering, and which had left a portion of its load behind it on Mount Jura.

This view would afford a natural account of the production of Holland, and of a great part of that quarter of Europe, which consists entirely of sand, and whose magnitude appears to me very far to surpass any deposition that could reasonably be ascribed to the present rivers. All this sand may be conceived to have been hurried along by that mighty stream, and deposited when the torrent began to spread, and lose its force by diffusion. It is likely, too, that an immense quantity of this sand would be carried far into the ocean, and its deposition being there modified in various ways, by local tides and currents, might assume the character of horizontal strata, so as to lay the foundation for future productions of freestone or of killas. We might thus, by the help of this diluvian agent, complete the great circle of events, so elegantly pointed out by Dr HUTTON, but which the diurnal agents seem quite insufficient to fulfil.

As the sand was depositing upon the low countries, the blocks of granite, with their accompanying ice, from whatever quarter they originated, would still keep floating, and thus account for a striking fact stated by M. DE LUC. He observes, that

that the granitic blocks lying in the district between Berlin and the Baltic Sea, occur frequently, and almost constantly, in very numerous assemblages, upon the summits of the sandy hills with which that country is interspersed, whilst none are to be met with in the intervening valleys. That they also abound on the islands of the Baltic; and these blocks shew themselves upon the beach only in those places where the sea reaches the base of some of the hills on which they lie.

The present theory affords an easy solution of this fact. In the descending stream, these hills, constituting shallow sand-banks, would afford the first resting place for the floating blocks of ice, which, grounding upon them, would accumulate to very numerous assemblages, and there deposit their granitic charge, while all the other similar blocks flowed onwards, in the deep water between *.

We are thus enabled to give a tolerable account of the granite blocks; but the formation of valleys, and the excavation of lakes, in particular of the lake of Geneva, remain to be explained.

* This aid, by which our diluvian wave is so much assisted, can be of no such service to M. DE SAUSSURE's hypothesis, as he has originally framed it. He conceives (art. 210, p. 141. vol. i.) that, at a period when the mountains were covered with water, the crust was broken which defended certain caverns then void, and the waters rushing into them with violence, left the mountains in their present state, and, by their retreat, produced the diluvian torrent. It is plain that such a torrent could derive no assistance from the blocks of ice. For when this water, in its previously stagnated state, touched the solid earth, if any blocks of ice were there, they would adhere to that solid mass, and would not be carried off by the retiring waters; and where this water lay deep upon the solid mass, its ice, if it had any, must have been floating at the surface, and could not be attached to blocks of stone, lying of course at the bottom.

It is obvious, from the mode in which this topic is introduced by M. DE SAUSSURE, (which he does, as he expressly says, to meet the impatience of his reader,) that he is not satisfied with it himself, nor can it bear the slightest examination.

plained. I trust, however, that the same principles will extricate us from this difficulty also.

If my view is correct, as to the violent manner in which our continents have risen from the bottom of the sea, to their utmost elevation in the atmosphere, it is quite obvious, that the cold and hard external crust, while it communicated such shocks to the ocean, must itself have undergone the greatest agitation, and must have been rent and broken in every conceivable mode. The stone, in liquid fusion, introduced into the rents, would assist the elevation, in so far as it tended to facilitate the shifts, by enabling one mass to slide on the other; but forcing its way upwards, this liquid would at last reach a temperature, in which, as we have said, it would congeal; its further progress in that direction, with respect to the neighbouring substance, being thus effectually stopt, and the propelling force from below continuing to act, the local elevation would be converted into a more general one, either where the strata were in a flexible state, by means of an horizontal thrust, producing an elevation along with the convolution of the strata, (in a manner lately pointed out in this Society), or, where the neighbouring substances were inflexible, by a penetration of the liquid through the mass, giving rise also to a vertical heave of the whole. In either case, a number of rents would be formed, in the hard outer crust, which would widen upwards as the heave advanced *, thus forming the rudiments of valleys

* This elevation may be illustrated, by the familiar example of what happens in the act of digging a piece of firm soil. The gardener first thrusts his spade into the unbroken ground, then leaning on the handle, gradually forces the flat iron upwards; by this means, a heave of the soil takes place; the middle part being raised, while the sides remain more or less attached to the firm soil. A separation between the two is the consequence; and a formation of rents open upwards, which gradually become wider and wider as the spade rises.

of every degree of wideness, from the narrowest ravine to the most open vale.

All this progress, or at least great part of it, being performed by successive starts, each of which, while under water, producing a tremendous wave; the mass, in rising, would be repeatedly exposed to these diluvian torrents, some formed by itself, and some by neighbouring elevations, so as at last, after long exposure to agents, partly diluvian and partly diurnal, it would arrive at its present situation and condition.

In consequence of the diversity of these elevations in place and in magnitude, acting upon substances of every sort, an endless diversity of effect would be the result. In some cases a rent, in consequence of the locality of the heave, would be rendered both large and deep in the middle, while it remained nearly closed at both ends. Water, therefore, could not flow through it without stagnating by the way, and thus a lake would be formed, the depth of which might be very great in the middle, though its extremities were shallow. This applies to the formation of the lake of Geneva, either before or since the passage of the granitic blocks. It is applicable also to all lakes which occur in alpine or rocky districts. It will appear in what follows, that an account no less satisfactory may be given on other principles of those which belong to alluvial countries.

An example of the relative changes among rocks, produced by motions of this sort, occurs in the mass on the coast of Berwickshire, with which we have been so much occupied in a former meeting, as affording a display of the convolutions of the strata. Upon this coast, the killas and sandstone meet on the East near Eyemouth, and on the West in the parish of Cockburnspath, at the Siccar Point, where the junction is beautiful-

ly

ly displayed. In the neighbourhood of both junctions, the sandstone strata, laid open by the shore, present to view a striking picture of former revolutions, as I have endeavoured to represent by two sketches taken upon the spot. One is at the Hallahole near the Press, between Berwick and Eyemouth (Plate VII.) on the east; and the other at the Coveshore (Plate VIII) in the parish of Cockburnspath on the west.

In both, the sandstone, remote from the junction, is seen in an horizontal position, which seems to be its general character, and which upon the West it maintains to a great extent; but in the neighbourhood of the junction, the beds become absolutely perpendicular, in a rock which, in both cases, rises to the height of thirty or forty feet. This change of position takes place differently in the two cases. That upon the East is sudden and immediate, the whole change being performed in a single cliff, at the bottom of which the beds are horizontal, and at its summit vertical, nay, leaning over upon themselves; on the other it is gradual, the strata being seen in succession to pass through every intermediate declivity, the change occupying more than a mile of coast.

This local elevation seems unequivocally to denote a great perpendicular shift. Either the sandstone mass has sunk and left the killas behind it, or the killas has risen from below, leaving the sandstone, and dragging its contiguous beds partly up along with it. As we know that the whole once lay deep below the sea, and that it is now raised, it seems more simple to ascribe these changes to one action, and to believe that the last supposition is the true one.

A fact which I witnessed in Calabria, not long after it occurred, belongs to the same class, and may bear a similar interpretation. What is called the Plain of Calabria is an alluvial

district, situated along the western coast, behind which there rises a ridge of primitive mountains. When the terrible earthquake of 1783 took place, a very extraordinary circumstance happened, the remains of which I went to see in 1785, and found it corresponding to DOLOMIEU's description. A naked scar of red earth, facing the plain, made its appearance upon the primitive mass, all along the line of junction between the two; this scar being ten or fifteen feet high, and appearing almost universally in a tract of many miles. DOLOMIEU has given an ingenious theory of this phenomenon, which appeared to me satisfactory at the time. He supposes, that in consequence of the agitation of the alluvial mass by the earthquake, it had undergone a subsidence, or *tassement* (as it is expressed in French), similar to what happens when a bushel of wheat is struck by the hand; and that in consequence of the subsidence of the loose country, the firm country had been left behind. I am now, however, inclined to suggest a different explanation of the same fact, and to connect it, by analogy, with some of those lately mentioned, by conceiving that the middle, or rocky mass, may have been raised, leaving the alluvial mass behind it, and that its motion has been the proximate cause of the earthquake. It may further be observed, in favour of this view, that if the alluvial mass did subside in the manner pointed out by DOLOMIEU, the districts in the neighbourhood of the sea must have been submerged. It would have been easy, if such a conjecture had occurred on the spot, to bring it to the test of observation; for the opposite side of the coast of the peninsula must have furnished some facts either in confirmation or refutation of the idea. I mention it here, as a hint to future travellers, in tracing the result of earthquakes.

I cannot too strongly recommend to geological travellers, the examination of those scenes where earthquakes, and their attendant

tendant waves, have exerted their influence, and which have probably left behind them very striking monuments of their power. I conceive that in this way, the doctrines already advanced in this paper, and which I am now about more fully to illustrate, will be submitted to the test of direct observation.

The fact which I have met with most strictly in point, occurs in HUMBOLDT's Account of Mexico, *Eng. Trans.* London, 1811, vol. ii. p. 212. At San Pedro de Jerullo, "in the month "of June 1759, a subterraneous noise was heard. Hollow "noises of a most alarming nature (*bramidos*) were accompa- "nied by frequent earthquakes, which succeeded one another "from fifty to sixty days, to the great consternation of the in- "habitants of the Hacienda. From the beginning of Septem- "ber, every thing seemed to announce the complete re-esta- "blishment of tranquillity, when, in the night between the "28th and 29th, the horrible subterraneous noise recommen- "ced. The affrighted inhabitants fled to the mountains of "Aquasarco. A tract of ground, from three to four square "miles in extent, which goes by the name of the Malpays, "rose up in the shape of a bladder. The bounds of this con- "vulsion are still distinguishable in the fractured strata. The "Malpays near its edges is only twelve metres (thirty-nine "feet) above the old level of the plain, called Playas de Je- "rullo; but the convexity of the ground thus thrown up, in- "creases progressively towards the centre, to an elevation of "one hundred and sixty metres (five hundred and twenty-four "feet)."

In this most striking and interesting scene, we have an actual specimen of those violent and sudden operations by which our continents have been raised to their present position, according

cording to my view of Dr HUTTON's Theory; and had this event come to his knowledge, which happened in his day, it might have induced him to admit the probability of those sudden elevations, indicated by so many facts.

The process of elevation, whether performed gently or rapidly, is free from a difficulty to which the systems of both SAUSSURE and WERNER are exposed: both of these geologists conceive that our continents and rocky districts were once covered with water, which has since flowed away, these rocks maintaining their original position; now, to lay a rock bare in this manner, we must dispose not only of the water which covered the immediate mass of rock, but also of that body of the same fluid which occupied an equal level all over the globe. This difficulty was strongly felt by Professor PALLAS, who says, (*Observations sur la Formation des Montagnes*, p. 79.), that were the summits of the mountains supposed to have been covered, the mass of water required to equal and surmount them round all the globe could not be disposed of within the earth, even were its inside made up of caverns: On that account, he denies that the summit of the hills has been covered. He burdens himself, however, with a very considerable share of the same difficulty, by supposing that the sea had stood at such a level as to submerge hills of 100 fathoms high.

According to our theory, there is no such embarrassment. We suppose these low hills, as well as the high ones, to have been raised from the bottom of the sea, which need not be considered as ever having stood above its present level. And I think myself authorised by the facts stated in the course of this paper, in deviating so far from the Huttonian hypothesis, as to believe that the elevation of the land was performed

formed by successive starts, similar to volcanic eruptions, though far more rare and more powerful; and that the percussions impressed by these starts upon the waters of the ocean, were such as to form waves, sometimes of a moderate force, as those at Lisbon or Callao; sometimes of overwhelming magnitude, and capable of producing the effects described in the Alps, in Germany, and in Russia.

As the inferences derived from these distant facts are called in question by some gentlemen of the highest authority in this Society, I am happy to have it in my power to produce a set of observations made in this immediate neighbourhood, which seem in a manner no less satisfactory, to lead to similar conclusions. These are the subject of the second part of this communication.

PART II.

ON THE

REVOLUTIONS

OF THE

EARTH'S SURFACE.

PART II.

BEING AN ACCOUNT OF THE DILUVIAN FACTS IN THE NEIGHBOURHOOD OF EDINBURGH.

IF such tremendous agents did in reality exert their influence in the Alps, it is not conceivable that other countries, situated lower, and composed of materials much more frail, could have been spared. We hear in fact of similar traces, more or less distinct, in all quarters of the globe. From the bones of animals, natives of the hottest climates, which are found over a frozen region of vast extent in the Russian empire, PALLAS * concludes, that an enormous torrent had transported their carcases across the ridge of Tartary.

* Observations sur la Formation des Montagnes, p. 71. Nov. Com. Petr. tom. XVII. p. 576.

On my return from the Alps, looking for traces of the same agents in this country, I found them in abundance, particularly in the neighbourhood of Edinburgh; and the circumstances of this sort which I have met with, both on a large scale and in detail, seem to afford more precise information as to these events than has hitherto been furnished by the alpine phenomena.

In order to acquire principles upon which these observations may be made to advantage, and by which the truth or falsehood of the systems to which they lead may be brought to a certain test, it is of importance to examine the results of similar actions, in such analogous cases as lie in all respects within reach of observation. If a torrent, like that which is supposed to have inundated the Alps, had flowed over this country, it must have left behind it traces of various sorts, resembling in some degree those that occur in the course of any common river which has recently overflowed its banks. Thus in both cases, sand and mud, and loose stones, must have been transported and deposited; and fixed objects must have been overwhelmed and abraded, by the action of the water and of these moving bodies: The relation of the stream to these objects, either met or transported, is very different, it is true, in the two cases; but a sufficient agreement exists between them to guide us on the present occasion.

It is an undoubted truth, that where an obstacle occurs in the course of a fluid, which is in the act of transporting and depositing heavy substances, the deposition in the neighbourhood of that obstacle undergoes considerable modification. The theory of these modifications would be difficult to determine; but their effects may easily be traced, by observation in the bed of any stream after a flood, or in the drifting of snow, fallen during a high wind, or which is in the act of falling.

Where

Where the obstacle is high and narrow; where its height, for instance, is at least equal to its breadth, we perceive that a stagnation of the fluid takes place on the side towards which the stream is flowing, and a deposition is formed of the transported substances, constituting a tail or prolongation, which extends in the direction of the stream, by a gradual descent to the distance frequently of eight or ten times the height of the obstacle. At the same time, an acceleration is occasioned at certain places in the neighbourhood, by which the general deposition, which was going on at the time, and which would have been universal had no interruption occurred, is there prevented. This acceleration takes place along that face of the obstacle which fronts the stream, along both its sides, and along those of the tail, forming by the stagnation just mentioned: the consequence is the production of a hollow or depression in all those places, below the level of the general deposition in the neighbourhood. The case is different where the obstacle is of great breadth compared with its height. When its breadth, for example, is five or six times greater than its height, the effect is often reversed, and an excavation is occasioned on the side towards which the stream is flowing.

The action of a current of water upon sand, or of wind upon snow, previously deposited, produces effects similar to those just pointed out. Thus, a firm body, occurring in the midst of such an assemblage, mitigates or prevents the action behind the obstacle, that is, on the side towards which the current is flowing, and, at the same time, augments the corrosive energy in front of it, and along the two sides. Effects are thus produced similar to those in the case last mentioned; and it may be difficult in many cases to determine whether a particular assemblage has been produced, by a modification of the first deposition, or by a second action upon an assemblage previously

viously formed. The action of a current, with the assistance of the solid masses of every size transported by it, upon the substance of any solid rock opposed to it, is subject to certain laws, the principles of which must, in many respects, be common to it in the two cases just mentioned, as we shall have occasion to point out more fully in the course of this paper.

In attempting to apply these principles to the great scale of geology, and to vindicate my opinions on this curious subject, I shall appeal to a series of facts which are very accessible to this assembly, the greatest part of them lying within two or three miles of this city. In that view, I have given, along with this paper, a plan, on actual survey, taken on this account, of a small district in the neighbourhood of Edinburgh, comprehending the Corstorphine Hill and its immediate neighbourhood. I thus hope to indicate the place of each specimen alluded to, in such a manner, that, provided the rock remains in existence, it may be in the power of an observer to discover it at any future period, however much it may have been concealed by the accidents to which such specimens are perpetually exposed.

The country in the neighbourhood of Edinburgh is what all are agreed to call Secondary, consisting of beds of sandstone, and occasionally of limestone and coal, interstratified with thick assemblages of shale, in loose and frail strata. This mass is traversed with the utmost irregularity, by dikes or veins of whinstone, which occur also in vast interjected masses, sometimes lying in great amorphous blocks, and sometimes in thick beds, parallel to the strata. The strata, themselves, as might be expected, are thrown, by means of its intrusion, into much irregularity, and though nearly parallel to each other in any particular spot, exhibit the utmost variety, when different places are compared together, as to their dip and direction. This contrast

contrast is conspicuous in Salisbury Craig on the east, and in Corstorphine Hill on the west of Edinburgh. Each consists of a thick mass of whinstone, parallel to the strata beneath it, which, in the first mentioned hill, dip rapidly to the east, and in the second to the west.

The surface of this district, together with the alluvial part of its mass, bears every mark of the effects which a wave of sufficient magnitude to overwhelm it, might be expected to occasion upon so multifarious an assemblage.

Raised from below by the violent and abrupt means already alluded to, in my last communication to the Society, this district would present to a stream overwhelming it at any subsequent period, numberless points of attack. Many of the rocks being rent in various ways, the hardest parts being in a shivered state, would easily be carried forward. The soft beds of shale or slate-clay being laid open to the attacks of the current, would be deeply abraded by its action, and thus masses, both stratified and unstratified, that were originally unbroken, would be undermined, and, yielding to their own weight, would add to the quantity of moving matter, and extend the field of attack upon the weaker parts. The water would thus be loaded with a multitude of blocks of every size, shape, and quality, and with a quantity of clay, which being soon reduced to mud, through which these stones were irregularly and confusedly scattered, would flow at the bottom of the water, and along with it, and would be deposited, according to the laws already pointed out, when the stream approached to a state of rest. Such seems to have been the origin of that body of compact blue clay which forms a material part of our low districts, bearing every indication of having flowed as a mass into its present situation; for it is totally devoid of stratification, though frequently of great thick-

ness,

ness. This mass shews itself in several places, in the bed of the water of Leith, where the banks have been laid open by natural or artificial means. It was well displayed formerly, and may still be seen above the Bells' Mills Quarry, and is now exposed to view upon the right hand, after crossing the Dean Bridge, on the old road to Queensferry. It here presents to view a face of about twenty or thirty feet deep, though it often extends to forty or fifty feet. We find it also upon the shore to the west of Leith, as laid open by the sea; and I am informed by the person who conducted the work, that at the Fort in that neighbourhood, in a search for water, it has been penetrated to the depth of eighty feet from the surface, being fifty below high-water mark. It is obvious, that the power of such mud, when flowing as a stream, in transporting heavy bodies, and in abrading assemblages previously formed, must bear some relation to the resistance which it would oppose to any object forced through it, and of course, that its power in these respects must have been much superior to that of pure water. I conceive also, that a deep stream must exert a greater power of transportation and corrosion than one which is shallow, flowing with the same velocity.

The existence of assemblages of this sort, affords, by its simple testimony, a powerful argument in favour of a stream having overflowed this country, superior in magnitude to any known river; and the facts seem to meet the challenge held out by Mr Playfair in the following passage, *Illustrations*, art. 366. "Lastly," he says, "if there were anywhere a hill, "or any large mass composed of broken and shapeless stones, "thrown together like rubbish, and neither worked into gra- "vel, nor disposed with any regularity, we must ascribe it to "some other cause than the ordinary detritus and wasting of "the land. This, however, has never yet occurred, and it "seems

" seems best to wait till the phenomenon is observed before " we seek for the explanation of it."

Now it appears to me, that these vast assemblages, in which blocks of every size, and shape, and quality, some sharp, some round, are confusedly scattered through clay, are inexplicable by any diurnal cause, and do call for some particular solution.

Such parts of the torrent as encountered less of the strata of shale and clay, would hurry along with them the comminuted sandstone, and deposite it in the form of sand and of gravel. Vast accumulations have thus been formed in all our lower districts, the external figure of which, and of the clay, has acquired, as we shall soon have occasion to point out, a character peculiar to itself, and having externally a smoothness and regularity, which forms a striking contrast with the abrupt and most irregular dislocation which very commonly occurs in the solid mass within.

In the midst of this general wreck of all the frail parts, the strongest masses, principally those which, like Arthur's Seat, have been powerfully pervaded with whinstone, would resist and defy all the impetuosity of the stream. The principles which we have endeavoured to lay down, as to the influence of firm obstacles on depositions and abrasions, would thus be brought into action.

The rock upon which the Castle of Edinburgh stands, together with the site of the Old Town, exhibit the most perfect example that could be conceived of the application of these principles. The rock itself, about two hundred feet in height, above its base, and bare on three-fourths of its circumference, consists of one of the most complete and uniform masses of whinstone that is known in this country. Its form is rudely cylindrical, and from it the ridge upon which the Old Town stands,

stands, composed partly of deposites, and partly of protected strata, extends, gently sloping, for about a mile to the eastward, from the Castle to the Abbey of Holyroodhouse, where the tail terminates. Round the western, southern, and northern sides, a hollow valley occurs, which, towards the north, is still a marsh, and was once a lake, being known by the name of the North Loch.

Corstorphine Hill, which, as seen from Edinburgh, occupies the horizon to the north-west, affords, in one respect, an example of the other case just mentioned. It consists of a ridge of about a mile and a half in extent, rising in the middle, declining gently at both ends, and pointing from north to south, with a declination of about 20° to the east. It presents a smooth face of whinstone to the west, towards which the mass dips in parallelism with the strata beneath it. Upon its eastern side a hollow valley occurs, in which the old castle of Craigcrook stands, and from its southern extremity a tail extends to the eastward, lying between Ravelstone and Murrayfield, upon the southern face of which Murrayfield stands.

Thus, the Castle of Edinburgh, gives an example of the effect of a narrow obstacle; and this hill, of a broad one, in so far as it has a valley on the side towards which the stream was flowing.

We have endeavoured, in the last communication to this Society, to account for the formation of such lakes as occur in alpine and rocky districts. The circumstances just pointed out, explain the formation of those which belong to districts formed of frail and moveable substances. At Lochend a striking example occurs, of a lake produced upon the upper side of an obstacle, in consequence of local acceleration.

Immediately on the east of Corstorphine Hill, a set of firm rocks, or little hills of sandstone occur, rising up from this hollow,

low, or standing upon its eastern side. Of these, Ravelstone, Craigleith, and Blackcraig, are the principal, well known as excellent quarries. From each of them a tail or prolongation extends to the eastward, formed chiefly of the blue clay already mentioned, together with beds of sand and gravel. These decline very gently, and maintain, to a considerable distance, the individual character given to each by the firm mass producing it. These ridges, however, are occasionally interrupted by the interference of the same principles; as we see well illustrated near the rock of Craigleith Quarry, by which the tail extending from the Maiden Craig, (another sandstone mass to the westward of it,) is abruptly cut off.

From Corstorphine Hill to the eastward, the country embracing all the space between Edinburgh and the sea presents one continued series of ridges, upon one of which the New Town of Edinburgh stands. It is an important circumstance, that these ridges maintain a very correct parallelism with each other, with the tail of the Castle rock, and of the Calton Hill, and with the alluvial prolongations that extend to the eastward from all the eminences of this neighbourhood. And a series of parallel ridges occur also on the south side of Edinburgh, extending from all the rocky eminences, as may be well seen on the road leading to Dalkeith, which passes over several of these; one of the most remarkable of which is, that on which the village of Libberton stands.

Such an arrangement cannot have been the work of the diurnal waters produced by our common rains; for the course of such waters, flowing by the action of gravity, and guided by the general slope of the country, which declines towards the Frith of Forth, ought to have produced depositions nearly at right angles to those under consideration. It is in vain that a vast duration is ascribed to the influ-

ence of an agent, unless it can be shewn, that its action has a tendency to produce the alleged result. If it has a tendency to produce a different result, that difference would be augmented in proportion to the duration of the action. Now, the diurnal operations are everywhere found in the act of corroding and altering the forms here alluded to *; but they are nowhere seen to produce them. This class of facts, on the other hand, all conspire in giving probability to the hypothesis of a diluvian wave, which affords an easy explanation of all the large features of this country.

An important principle of the theory of running streams must here also be considered, namely, that the shape assumed by such a stream flowing through sand or other loose matter, bears a distinct relation to the magnitude of the stream; the radius of curvature of its bendings being in proportion to that magnitude. Thus, all the water collected from this neighbourhood, is capable of producing no more than a paltry brook, as appears from the Water of Leith, which we see meandering between two of the ridges just mentioned. This meandering course, suits the diminutive size of the brook; whereas these ridges being straight, or, mathematically speaking, having a curvature whose radius is of infinite length, we are led, by a very obvious analogy, and in concurrence with what has been observsd in other parts of the globe, to believe that a cause very different from any now in activity, and far more powerful, has exerted its influence upon this spot; that a stream has

* As is very apparent upon some of the ridges last mentioned, as we see on the road to Dalkeith, just as we leave Edinburgh. Some ravines there present themselves in front, and on the right hand, descending the northern side of the ridge, and denoting a genuine diurnal action, in obedience to the mere action of gravity.

has flowed over it, capable of overwhelming and disregarding objects by which the Nile or the Ganges would have been turned out of their course.

But the testimonies in favour of this hypothesis are not derived from these large features alone; and it is not conceivable, that such agents could have been at work, without leaving behind them indications of their influence still more unequivocal. These occur in the very places indicated by the theory, and exhibit remarkable instances of abrasion. In order to investigate them with success, we must have recourse once more to the effects produced by one of our common streams.

Where a firm rock of any kind has been exposed to the action of a rapid river, its surface acquires in consequence of that abrasion a peculiar character, which every one recognizes at a glance, but which it is difficult to describe in words. The most obvious and universal effect of such an action, is the rounding of all the original angles of the rock; not only the prominent, but also the entering angles. For where an original hollow has occurred, coinciding at all with the course of the stream, the water has undergone an acceleration along that hollow, and has excavated for itself a waving groove more or less longitudinal. The whole has thus acquired a peculiar character, by an assemblage of flowing lines, which recalls the water-worn state of the rock. Another set of forms also present themselves in all such cases, which could not easily have been foreseen, and whose existence we learn only from observation of the fact: we observe, that the surface is in many parts excavated by shallow depressions of various sizes, which I shall distinguish by the name of *scoopings*, as resembling the effect which would be produced upon a soft body by the oblique blow of a spoon or scoop. I

conceive that they have in fact been produced by the action of eddies of inferior force to the main stream, but acting in company with it in different, and sometimes opposite directions. These various corrosions going on together, have each produced its peculiar effect; and most of them being concave, their meeting has given rise to the set of waving angular ridges which constitute the most unequivocal feature of a water-worn rock. These angular forms differ completely from those which occur in the broken surface of a rock. These last are acute, rectilinear and abrupt; while those others are continuous, flowing, and having their angles very obtuse; so obtuse in some cases, as not to be visible, unless the light strikes upon the rock in a peculiar direction *.

In a small but rapid brook near my house in the country, these forms occur on the surface of a smooth bed of sandstone over which it flows. I observed lately, when the brook was low and clear, that, to a certain distance below each of these obtuse-angled ridges, the rock was covered with green moss, while above the angle it was bare. The mode in which these forms are produced and maintained, seems thus to be pointed out: the main stream being possessed of just power enough to keep the rock clear of moss, and the eddy being too weak for this purpose. In a flood, I presume that the eddy acquires such power, that the whole rock is cleared.

In

* I have endeavoured, as yet without success, to make or procure an adequate representation of these forms; but I do not despair of overcoming this difficulty, and of being able, on some future occasion, to lay something of the kind before this Society that may not be unworthy of their notice. In this undertaking, I hope for the assistance of a very masterly artist, who is interested in the investigation, and who has already rendered me great services in this and other pursuits.

In whatever manner we account for the production of these forms, it is certain, that they present themselves on the surface of water-worn rocks. I have also observed them upon the surface of a mass of snow which had been acted upon, and partly removed by a strong wind. As the abrasion occasioned by a fluid in motion seems alone to possess that power, we may reasonably conclude, then, that a fluid has acted where such forms occur.

Now, it is a fact of which I shall presently lay various examples before this assembly, that the very rocks over which, according to the theory advanced in this paper, torrents of water have flowed, loaded with sand, and gravel, and large stones, and accompanied with streams of mud, are found to exhibit at their surface all the characters of abrasion lately mentioned; —the rotundity and flowing character;—the excavation of hollows into the form of waving grooves;—the concave scoopings, and the obtuse-angled, and waving ridges. Circumstances, then, seem to justify the conclusion, that, in fact, mighty torrents have traversed these districts.

In addition to the facts mentioned, and in company with them, another set also occur in these scenes, which powerfully corroborate the same conclusion. As stones of considerable bulk are often carried down by torrents, it is reasonable to expect, that upon rocks along which they have been hurried, and on which they could not fail to act as grinders, traces should shew themselves of that passage by scratches and abrasions of various sorts; and I have little doubt, that such will be found, when the effects of great floods in rapid rivers are properly examined; especially where a stream of mud has accompanied the torrent. Not having had occasion, however, to visit any scene of this sort, since the importance of the observation occurred to me, I have as yet, only met in rivers with

with cases in which the surface of the rock has been dressed to smoothness, and in which the abrasion shews itself in the general rotundity of the grooves and scoopings, and in the obtuse angled and waving ridges just described *.

But what I have hitherto looked for in vain in common rivers, occurs universally in the diluvian scenes, where there is reason, from other circumstances, to believe, that a powerful abrasion has taken place, and where the surface has been protected from the injuries of the weather. Where it has been exposed to that injury, we generally find, that the large features of dressing, the grooves and scoopings, and obtuse-angled ridges, only remain. But where a mass of this kind, either by accident or design, has been followed under ground to where its surface has been protected by a covering of clay, an interesting and striking scene presents itself; the surface is found to resemble that of a wet road, along which a number of heavy and irregular bodies have been recently dragged; indicating that every block that passed, and every one of its corners, had left its trace behind it; and these are rendered very distinctly visible, when the surface is drenched with water.

In many cases these furrows or scratches have been so deep as to resist all the effects of the weather, and shew themselves in rocks that have been always exposed, sometimes many

* The only case which has as yet occurred to me, bearing any relation to the action here alluded to, arose from a cause seemingly quite insignificant. In a neighbouring county, a country house, situated upon the slope of a hill, was assailed by a sudden torrent of water, produced by the bursting of a thunder-storm on the hill above. The impetuosity of the stream was such, that it forced its way through the under storey of the house, carrying along with it quantities of sand and gravel, and stones of considerable bulk. Happening to be upon the spot a few weeks after the accident took place, I observed, that every stone, as it passed through the house, had left a rut or scratch behind it, upon the flags over which it passed.

many yards in length. Occasionally, single scratches, and parallel sets of them, deviate by five or six degrees from the general direction; but the important circumstance is, that such deviation is rare, the very great majority of both sets agreeing in parallelism with each other, and with the general direction, not only of the scoops and grooves of the rock upon which they occur, but also of the ridges and large features of the district. A rock covered with these furrows, has externally an appearance greatly resembling what is called Slickenside, with this difference, that in the slickenside, we can always discover some proof that one portion of the main rock has performed a small slide upon the other; whereas, in this case, every thing shews, that the rock under consideration has stood firm, and has been abraded by a number of bodies in motion. The circumstance just mentioned, of occasional deviations from parallelism, seems also to distinguish this form from the slickenside; in which last, I believe, the lines are invariably parallel *.

The direction of the stream in the neighbourhood of Edinburgh, as indicated by the medium result of a number of observations, appears to have been from 10° S. of W. to 10° N. of E., by true bearings taken with a needle, and allowing 27½ degrees west of north as the variation; and I have met with

* They are also distinguished by this, that in the case of Slickenside, the rock has always upon it a crust of calcareous spar or zeolite, which seems to have occupied a vein. Both sets seem to have been the result of mechanical action. The slickenside has been produced, I conceive, in the Plutonic regions, at a time when the mass in general has been so far cooled, as to be solid, though sufficient heat has remained to keep the fusible matter, as carbonate of lime or zeolite, which filled the vein, in a state at least of semifusion; so that in the sliding of one mass on the other, it has acted like grease in the wheel of a carriage: this theory accounts for the parallelism of the lines of slickenside.

with no case deviating more than 10° or 12° from that average on either side *.

Specimens.

I shall now describe the situation of fifteen specimens around Corstorphine Hill, denoted in Plate IX. by the number of each inclosed in a little circle.

No 1. The first is upon the rock at Craigleith, part of which is now worked as a quarry. It is a very complete and firm sandstone, and, as I have already mentioned, stands up, in the course of our supposed stream, to the height of forty or fifty feet, having a long projecting tail to the eastward, similar, on a small scale, to that of Edinburgh. It has likewise, on its western side, an excavation similar to that which forms the North Loch, but on a proportionally small scale.

This rock had lain bare, and open to the day on its westerly front, and it everywhere presents to view, where not concealed by the rubbish of the quarry, that rotundity of form which might be expected in such a situation, though, by its exposure

* I am aware, that the usual mode is to describe the direction of a current at sea, by stating the point towards which it flows. But my object, on this occasion, being to trace the origin of these currents, I have been induced to follow an opposite mode, and in general to denote the course by the point from whence the stream has been supposed to flow. In the following descriptions, the principal object of which is to mark the place of each specimen, I have frequently omitted the direction, in order to avoid interruption. But these directions have been carefully observed, and may be seen by turning to the page at the end of this paper, where they are all placed in one column, each opposite to the name of the spot, and to its number.

posure to the air, it has here lost every other symptom of diluvian action. Another face of the same rock, sloping to the south, which occupies the left hand mass of rock on the entry to the quarry from the south, which has lately been freed of its alluvial covering, exhibits the same rotundity of form, with the addition of the more minute circumstances of dressing, in high perfection. The space here laid bare is about ten paces by three. The upper portion is nearly flat; a great part of the surface inclines rapidly to the south; indeed, in some places, it is almost perpendicular. The perpendicular face, as well as the rest, is covered with furrows and dressings, indicating that the grinders had been pressed against the rock by the impetuosity of the stream, independently of their gravity; for almost the whole of these dressings are horizontal, or nearly so. There are some, however, which cut the rest at an angle of five or six degrees, or even ten degrees. The average direction is west, five degrees south *.

No. 2. The second specimen is of small size, but is well characterised, differing in no essential point from the last. It appears on a space of only two or three square yards, close to the road side, at the remains of an old quarry, called the Maiden Craig, about two hundred yards west of Craigleith, and opposite to the lodge of Ravelstone House. This rock, which is of sandstone like the last, has also a tail, interrupted, as mentioned above, very distinctly by the diluvian excavation on the west of Craigleith.

* Since this paper went to press, the valuable specimen here mentioned has been almost entirely concealed by the mettle of a road thrown upon it. The rock, however, remains entire, and may be cleared by any future observer.

No. 3. The third is within the court of the old farm yard of Ravelstone. The greatest part of this court consists of a rock entirely bare, and nearly horizontal; the whole surface of which exhibits the dressings in the most distinct manner, being entirely composed of furrows, some of which are of a large size.

No. 4. The fourth specimen occurs near the foot of Corstorphine Hill, upon an old quarry, called the Well Craig, within two or three hundred paces, bearing east 25° south of the old castle of Craigcrook. It presents the dressing very distinctly, and, like the two first specimens, upon a rock sloping rapidly to the south.

These specimens are all upon sandstone. The remaining cases belong to whinstone, which, as has been said, occupies the upper part of Corstorphine Hill, sloping to the west. The ridge of the hill lies north and south, with an inclination of about twenty degrees west of north. It therefore meets our supposed westerly stream nearly at right angles. The ridge, as seen from Edinburgh, is very much serrated, being cut across by small ravines; and upon the north, after the general mass has sunk below the neighbouring country, the whinstone makes its appearance in various elevated masses in Barnton Park, lying in the prolongation to the northward of the longitudinal line; the most northerly of these elevations, which comes within forty or fifty yards of the old house of Barnton, rising not more than six or eight feet above the turf. These rocks, all of which, like the hill itself, present a sloping face to the west, exhibit, upon that face, all the large diluvian features already described: the rotundity, together with the grooves and scoopings; but none of the scratches, or other small features, are to be seen. The character, however, of the general operation is so well shewn, that the bearings of the stream

stream are distinctly marked, and agree with those already observed.

The ridge of the hill is about a mile and a half in length, and rises in the middle to a height, according to the map, of four hundred and seventy feet from the sea, perhaps three hundred from its base. Along the summit, which is everywhere planted, the rock is seen bare very frequently, in the midst of the young woods, and often shews itself also in the adjoining fields. Among these rocks, which I have examined again and again with care, so many examples occur, similar to those just described in Barnton Park, that the hill itself may be looked upon as one specimen illustrative of this important truth, in so far as the great features are concerned. In the following ten specimens, chosen on that same ground, the minuter indications of abrasion are also visible.

No. 5. In a place called Craighouse, upon the south side of the Queensferry Road, opposite to Barnton Park, and between it and the main hill, a mass of whinstone occurs, making part of the same longitudinal line. It was formerly worked as a quarry, for the purpose of paving and road-making, and is now clothed with young wood. In its highest point it exhibits all the large features of diluvian action, but none of the small ones. These, however, it appears, have been defaced by the action of the weather; for, on removing the young wood and soil from a surface of about twenty yards by thirty of the lower part immediately adjoining, I have discovered them in full perfection. Not only the grooves and scoopings make their appearance, but the surface is seen, when drenched with water, to be entirely covered with longitudinal dressings, as already described, in speaking of the specimens on sandstone. Where a rent has occurred at all in the direction of the current, it has guided the formation of a groove,

the zig-zag form of the rent being softened off into a waving hollow of uniform breadth, highly characteristic of the violent action of a stream vested with the power of grinding. It is remarkable, too, in more than one of these grooves, that at their Eastern extremity, after maintaining an equal wideness throughout, they suddenly spread to right and left, and lose their form. These grooves are three or four feet in length, by four or five inches in breadth. When a rent has occurred at right angles to the current, the rock has been ground across it, without visible modification of the action.

No. 6. From Craighouse Quarry (following the road which leads to Corstorphine along the western face of the hill, and passes on the east side of Clermiston) we arrive at a ruined cottage, on the left hand, at the mouth of a little ravine which here crosses the main ridge, and is called the Glen of North Clermiston. Close to the road, immediately upon the north side of the ruined cottage, and within the wall which encloses the wood, the whinstone almost bare, presents to view a continued series of parallel grooves, one of which is twenty paces in length, and others more. The hollows of these grooves are filled with moss and earth, which, being removed, and the rock drenched with water, a set of furrows shew themselves perfectly well characterised, having the same bearings with those of the other specimens, so as to lie quite at right angles with the longitudinal direction of the hill. This situation must be at least one hundred feet perpendicular above Craighouse.

No. 7. About two hundred yards farther to the south, below the road, stands a group of cottages, comprehended under the same name of North Clermiston. Opposite to these, and above the road, is a barren space which has been the seat of former quarries. Here several rocks are visibly dressed with the large diluvian features; and at one spot, just twenty-six paces

paces north-east from the nearest house, a fine set of furrows occur, having the direction west 10° south. Continuing along the same road, after passing through a young wood, we arrive at the farm-house of Mid Clermiston, lying below the road upon the westward. Two sets of enclosures occupy the space above the road, between it and the young wood, which covers the summit of the ridge; the most northerly of these, called the North Hill Park, contains two very interesting specimens, both situated upon the upper side of the field, and close to the wood.

No. 8. Near the middle of the upper side. Here a space of several yards square has here been laid bare by my former operations, and furrows and diluvian dressings are most distinctly visible, indicating a direction from west 10° south. One small set, consisting of four or five parallel scratches, produced probably by one stone, cut the rest at an angle of five or six degrees, indicating west 5° south.

No. 9. In the same field, and also close to the wood, about thirty or forty paces towards the south, another specimen of the same kind occurs very well characterised.

No. 10. Immediately adjoining to this last-mentioned field, on the south of it, lies another irregular field, called the North Mid-hill-park. From the middle and upper part of this field, a path leads up to the summit of the hill, in a direction nearly due east. This path crosses an open and nearly bare space, in the midst of the wood, at the distance of about fifty paces from the ruins of the signal-house on the summit. This space is of about half an acre in extent, and so bare, that no trees have grown upon it. The rock has here stood up in parallel tables, as is not unusual with whinstone, running nearly east and west; these have been completely rounded, as I conceive, by the current, and shew the large

large features of dressing very distinctly; the scoopings, in particular, are very well defined; the small features have been mostly defaced by the action of the air, but the removal of the turf has brought some of them very well into view. These agree with the grooves in the general indication of west 10° south. In several places where a rent has occurred in the direction of the stream, it has been excavated into the form of a waving groove, as already seen in No. 5.

No. 11. At the summit, a signal post had once been placed, and the house used for that purpose, remains in a state of ruin *. The rock of the summit (eight feet south-east from the south-east corner of the house) is dressed with some diluvian furrows, denoting west 10° south, as I found by clearing away some of the turf.

The ridge of the hill stretching to the south, shews everywhere the same general character, by the rounding of angles, denoting the action from the west.

No. 12. In a field called the South Mid-hill-park, in the farm of Mid Clermiston, in the south-east corner of the field, is a fine specimen, indicating west 5° south.

No. 13. The rock on which the summer-house of Ravelstone stands (the Stone View, as it is called by the country people) though completely exposed to the weather, shews some decided furrows. It forms the summit of the southern part of the ridge, and is only a few feet lower than the highest point. From it the scenes No. 1. No. 3. and No. 4. are still distinctly visible.

No. 14. In a pasture-field facing to the south, called the Sheep Park, belonging to Corstorphine Hill house, and immediately

* Since this paper was read, the signal-house has been removed, and its foundation only is now visible.

diately above it, is a good specimen, shewing the small features of the dressing; the direction of which agrees with that of the rest on this hill. This specimen lies contiguous to the fence, on the south side of the field, at the distance of forty-nine paces west from a wicket, close to some cottages.

No. 15. Close to the bottom of the hill, on the south-east, there is a specimen, in fine condition, near to the avenue leading to Belmont. As we go up this avenue, in a direction nearly due north, we leave two fields upon the right hand. The specimen here alluded to lies in the second or uppermost of these fields; being the same in which a whinstone quarry is now worked. The specimen lies near to the south-west corner of that field, being forty paces distant from the wall on the west, and forty also from that on the south. It presents one of the most perfect and complete examples I have met with, of a groove, with a set of scoopings corresponding alternately to each other in opposite sides of it, and some of the obtuse angled ridges in the highest perfection. The whinstone is also very distinctly dressed with the small features, which lie horizontally, and follow some wavings of the groove: their general direction is like that of all the rest, with slight variations on each side, of ten degrees south of north; at the same time, it is worthy of notice, that the surface of the ground declines rapidly from north to south.

I have thus pointed out fifteen specimens, within a circle two miles in diameter, surrounding Corstorphine Hill, each exhibiting both the large and the small features which indicate the action of water flowing with violence along the surface,

surface, and carrying large blocks of stone along with it. The number of examples concurring in the same indications of direction, might easily have been greatly augmented, as any person will see who examines the summit and western face of this hill; but I have judged that number to be already sufficiently great. I have taken care to denote each spot alluded to, in a manner so particular, that it might easily be found at this moment: I say at this moment, because, as is well known to every geologist, nothing is more precarious than the existence of such specimens, they being liable perpetually to be overgrown with vegetation, or covered with rubbish, or perhaps completely annihilated by the progress of the same operations which brought them into view. These specimens are by no means all equally interesting. Some of them are brought forward as simple indications of direction, and owe their value to the force which the argument derives from the concurrence of such a number of results. Those which are deserving of notice on their own account, are Nos. 5, 8, 10, & 15.

By considering together four or five of these examples, which lie at a small horizontal distance from each other, we shall be led to a conclusion which could not be deduced from any one of them singly. I have said, that close to the summit of the hill upon the west, an extensive space (No. 10.) of rock occurs nearly bare, displaying a succession of parallel grooves, pointing in the direction of the supposed stream, and upon which some of the minute dressings also are apparent. On examining this spot, two members of this Society, whose ideas on this subject are hostile to mine, immediately remarked, that the appearance reminded them of what they had seen in Arran, in the bed of the Garvalt, where the granite has been dressed by that torrent; and they alleged as a consequence, that the phenomenon was reduced to a common event.

I beg leave, in the first place, to avail myself of this testimony, in proof of the fact, that a stream, at least equal in force to the Garvalt, has, at one period, flowed over the rock at the summit of Corstorphine Hill.

It now remains a question of importance to say, from what source such a stream could have flowed, and how so much water could be collected. The spot under consideration, is not above twenty feet perpendicular below the extreme summit, so that the heaviest thunder shower, could scarcely produce there a sensible run of water; and if such a run were produced, it would have nothing to carry, the whole consisting of one hard and firm rock. The dressing is of large extent in itself, as the bare rock shews, and it is also connected, more or less intimately, with the dressed spots on the western face, Nos. 6, 7, 8, 9, 12, & 14., so that a stream of considerable breadth as well as power would be required to fulfil the conditions of the case. The difficulty is rendered more pressing still by two cases already mentioned; one at No. 11., and the other at No. 13., in both of which cases the rock is visibly dressed, in a spot which constitutes the local summit; the last of these, No 13. being the actual summit of this hill, and the highest point within the distance of many miles; and the other being separated from any higher ground by ravines, so that, in the present state of things, no water could flow towards either of them.

The only explanation that could be given of these facts, by means of the diurnal agents alone, must be obtained by going back (as has been done in a theory discussed in an early part of this paper), to some very remote period, when this hill was much higher, and more extensive than at present, and when a stream equal to the Garvalt could be collected above those spots, and could run over them, so as to produce the dressings under consideration; and, by supposing, that in sub-

sequent intervening ages, as in the hypothesis alluded to, all this additional mass of elevation and extent had been removed by the perpetual corrosion of diurnal actions.

This hypothesis might be maintained as within the limits of mere possibility, if all these dressings lay on one side of the hill, as this imaginary additional height might be carried to the opposite side. But as they occur equally on both sides of it, either upon the hill itself, or very near to its base, that hypothesis seems to be done away, as applicable to a part only of the phenomena *.

To

* It has also been alleged, admitting these dressings to have been the work of flowing water, that the action may have taken place at the bottom of the sea, and that the rock has since been elevated into its present position. Subscribing, as I do most heartily, to the doctrine of elevation, as advanced by Dr HUTTON, I am far from denying, that the very case here supposed, may frequently have happened; I even conceive that it must have occurred occasionally. I should not, therefore, object to this explanation of a dressed rock, that stood single in an extensive district. But that is by no means the case in the present instance: the phenomenon is far from single; it is surrounded, on the contrary, by facts, and classes of facts, calling for an explanation. This is afforded, if I do not deceive myself, by the hypothesis advanced in this paper. But the explanation just alluded to, would account for the dressed rock alone, and would be altogether inapplicable to the other classes of phenomena; by such a partial solution, we should therefore lose all the advantage derived in the theory proposed, from the mutual light which the large features and the small ones have thrown upon each other.

This explanation, too, would require no less an effort of imagination than ours; in fact, the two suppositions do not differ as to the magnitude of the exertion employed, but only as to the place of its original action, which we have conceived to lie somewhere to the westward. An elevation such as would carry this district from the bottom of the ocean into its present position, could not fail, (as we have endeavoured to prove in the first part of this paper), to be performed by starts, and consequently to produce waves. If the whole elevation took place at once, it would be of magnitude amply sufficient to fulfil, in some other quarter, all the conditions of our hypothesis.

It

To account for these dressings, therefore, we must call in the assistance of some extraordinary agent; and this assistance is at hand in the stream flowing from the west, the existence of which we have been led to imagine by the parallel ridges and tails which occur in this district. For the form, situation, and direction of these dressings are such, as a belief in the reality of that stream would lead us to look for. The mere arrangement of ridges stretching east and west, leaves it in doubt from which of these two opposite points the stream flowed; but the circumstance of the long depositions or tails parallel to these ridges and dressings, which occur upon the eastern side of obstacles, such as the rock of Edinburgh Castle, entirely removes that ambiguity, and proves that the stream must have flowed from the westward.

The *grinders* must then have been forced to move upwards along the westerly face of Corstorphine Hill, and in that mode

It might also be alleged, that the elevation was performed only in part, when the dressings took place; and that a further rise had carried the mass, on a subsequent occasion, to where it now stands; but nothing here seems to justify such an intermediate supposition. All the diluvian facts in this neighbourhood, that have come under my observation, concur in denoting *one* inundation overwhelming the solid mass of this district, which had been elevated into its present position by some still more ancient revolution of the same sort; this inundation being the last catastrophe to which it has been exposed.

Having endeavoured to illustrate the appearance of the dressed surfaces, by referring to abraded rocks in the beds of rivers, I find that some gentlemen, who had heard but a partial statement of my views, conceived it to be part of my supposition, that these dressings, like those in a river, were produced by water acting for a long time. But this is by no means my view; my theoretical notions limit the action upon the hill under examination, to the passage of a single wave, embracing a period of time that could only be expressed in minutes; but during that short time, I conceive the water to have been urged forward with such force, and to have carried with it so many powerful agents, that it has produced effects equal to the work of ages under other circumstances.

their action upon the rock would be most powerful, provided they were driven forward by sufficient force; the horizontal motion thus urging each stone against the object to be ground, (by an action similar to that which impels forward the chisel of a mason, dressing the surface of a stone, which acts in the direction of the axis of the chisel, forming an angle with the surface upon which it acts), whereas, if the declivity lay the opposite way, that same horizontal force would tend immediately to draw away the grinder, and prevent its action. We observe, accordingly, that though furrows or dressings do occur at a little distance to the eastward of the base, upon elevations presenting a western aspect, or lying flat, none such are anywhere to be found on a surface of rock inclining to the east.

It is further remarkable, how little the direction of this action has been disturbed by local circumstances. Thus, the furrows in No. 6. follow the medium course right up the hill, though close to the ravine on the south, and though, upon the other hand, at the distance of about two or three hundred yards from the abrupt termination of the hill itself. This seems to prove, not only that the stream flowed over Corstorphine Hill, but that it flowed over it with a great depth; for had the stream done no more than just cover the summit, its course must have locally obeyed the inclination of these surfaces. To pass along and disregard them entirely, seems to denote a great superiority of depth; and in calling it double, we probably do not exceed what is necessary. We have seen enough, however, to justify my assertion, that the stream must have been incomparably superior in magnitude to the Nile or the Ganges, since even the Corstorphine Hill, occurring in the course of these mighty streams, must have completely deranged their course.

This

This hill is stated to be four hundred and seventy feet above the sea. If we consider our stream as double the depth, or one thousand feet, we shall probably not go beyond the truth. This height is nearly sixteen times the altitude of the wave at Cadiz, which was sixty feet. The phenomena of the Alps, though very imperfectly known, indicate a magnitude double of this, by the mere position of the blocks on Jura, two thousand feet above the level of the Lake of Geneva. While I thus, however, ascribe great magnitude to the diluvian torrent, I am upon my guard against the excess of such impressions, and the means have already occurred, as I shall presently state, by which limits are assigned even to this colossal agent.

The geological truth supported by this concurrence of facts, both vast and minute, is confirmed by innumerable circumstances, which present themselves to view on all hands in this neighbourhood.

No. 16. At a place called Dickson's Craig, upon the road to Queensferry, about two or three hundred paces west of Barnbougle Gate, is an example of whinstone rock dressed like those mentioned, having a direction of three degrees south of west.

No. 17. Another also occurs at the sandstone quarry of Redhall, at the distance of about two miles south of Corstorphine Hill, and occupying the side of the valley directly opposite to it. This quarry is opened in one of the diluvian ridges, and the rock is covered by a bed of about twenty feet thick of the blue clay, having various large blocks of whinstone suspended in it, one of which is not less than forty cubic feet. The dressings point eight degrees south of west.

No. 18. On the hill of Ravelrig, in a young wood, near the eighth milestone from Edinburgh, on the road to Lanark, is a fine

fine specimen of dressed rock, which had been laid open by the forming of the road, and is still visible; the direction is fifteen degrees south of west.

North Berwick Law in East Lothian, has a tail extending towards the east; it has likewise a specimen of whinstone rock with the dressing upon it.

No. 19. Another specimen occurs on a hill, which makes one of a group of rocky eminences, to the southward of North Berwick Law, upon one of which the ruined tower of Fenton stands. The particular spot lies three or four hundred yards to the northward of that tower, and close to the eastward of the little village of Kingston. The rock presents to view furrows and scratches similar to those above described on Corstorphine Hill, with the additional circumstance, that the action of the stream has here undergone a visible modification, by the prominent form of some parts of the rock, in consequence of which the dressings have, in some places, been turned, to the amount of five or six degrees, out of the general direction; which, however, they resume gradually, in the course of a few yards. A curvature is thus produced, highly characteristic of the action of a torrent from the west. The scoopings, too, meeting the general direction in obtuse angles, are indicated in the most striking manner. The general direction, independently of these local disturbances, agrees with that in the neighbourhood of Edinburgh, being from fifteen degrees south of West.

The same law prevails in other parts of East Lothian, as appears by examination of the ridges at Spott and Pinkerton, which are very conspicuous objects from the great road between Edinburgh and Dunbar.

Observing the direction so constantly maintained in all this district, which, at the same time, is that of the valley in which the

the estuary lies, I began to suspect that the production of these effects may have been influenced by that valley; for though the torrent had sufficient power to disregard Corstorphine Hill, it may have yielded in some degree to greater eminences. If this law were established, we should be enabled better to understand these operations, by having their stupendous and unbounded magnitude reduced within tangible limits. I became, therefore, anxious to examine the facts which lay beyond the influence of this valley, where the indication of actions of a similar nature might be found. I recollected having seen some ridges of a diluvian character in the country immediately behind the promontory of Fast Castle in Berwickshire; and as this constitutes one of the southern flanks of the mouth of the estuary, I expected that some novelty in point of direction might here occur, and I was not disappointed; for I here met with a set of very distinct diluvian ridges, called Lowry's Knolls, the direction of which lies, by true bearings, west 35° north; so that they form an angle of no less than forty-five degrees with the general direction of the estuary, such at least as it occurs in East and Mid Lothian. As this new direction is assumed by the stream immediately on finding itself at liberty, we must suppose that the water, in this last-mentioned course, follows either the main direction, or approaches nearer to it than it did in the estuary. More observations are now much to be desired. With a view to them, and in consequence of a recollection which led me to suppose, that the Castle of Stirling was possessed of a diluvian character, I have (since this paper was read) made a little excursion to that place.

I discovered, however, that the elongation from Stirling Castle is entirely composed of solid whinstone, consequently that

that its form has not been produced by a diluvian action. On the other hand, I found myself surrounded by a set of ridges of alluvial matter, possessing a true diluvian character, and several rocks presented themselves, having the larger features. What gave a peculiar interest to these facts was, that these features agreed with the ridges, in indicating a direction between west and north, or east and south; that is to say, quite different from that near Edinburgh, but nearly agreeing with what I had observed in the lower extremity of the Frith of Forth. After considerable search, I discovered a rock of sandstone in Torwood, about six miles on this side of Stirling, possessing the diluvian dressing in the highest perfection. This rock is visible upon the south side of the road, just one hundred paces west of Torwood turnpike-gate; and the dressing is most conspicuous close to this, in the neighbouring wood, on the surface of a rock, some square yards of which I laid bare. The direction of this dressing confirms what in a great measure I had inferred from the large features, and from the ridges. Its direction indicates no less than fifty degrees north of west, or south of east, and thus differs very widely from that near Edinburgh, going still farther to the northward than what I had observed at the mouth of the Frith of Forth. It has a considerable agreement, however, with this last, and seems to favour the idea just suggested, that the direction in the neighbourhood of Edinburgh may have been occasioned by the local influence of the estuary, since the direction of the stream before entering it, and after quitting it, is nearly from north-west to south-east. This influence upon the direction of the stream, and on the deposition of loose matters, seems to bear an analogy to that which is exerted, on a small scale, in the abrasion of solid rocks, as seen on the ridge of Corstorphine Hill and at Kingston.

I have witnessed another set of facts, of which I can, as yet, produce but one example. The district along which the road passes from Edinburgh to Dumfries, in the neighbourhood of Noblehouse, exhibits a series of low hills, possessing the characteristic forms of craig and tail, which belong to those in the neighbourhood of Edinburgh, but such as to indicate the action of a stream flowing from the south-west. This is a high district compared to that of Edinburgh, and the waters may here be supposed in some measure to flow towards the estuary of the Frith of Forth.

These changes shew the importance of more extensive observations. At the same time, the concurrence of various indications, in pointing out one common direction at each place, seems to denote the influence of some general cause, and authorises a hope that the facts, when properly collected, will enable us to trace the general direction, and perhaps the origin, of this important agent.

Character of the Western District.

Another district of Scotland, which circumstances have led me to traverse in various directions, presents to view a state of things as different from those which have lately been described as could well be conceived. I mean, the south-west of Scotland, comprehending the stewartry of Kirkcudbright, the shires of Galloway and Dumfries, with part of Ayrshire, on one hand, and part of Cumberland on the other.

In that district, the straight and parallel ridges, so universal in this neighbourhood, and the forms of craig and tail, such as that of Edinburgh Castle, nowhere occur. The same assemblage of substances assume a different form, and present to view a perpetual succession of knolls, equally round at both extremities. This arrangement is conspicuous in the neighbourhood of Gilsland, which is surrounded with knolls of this description. It was there that a theory occurred to me, to account for the contrast of the opposite side of our island, which I have never since had occasion to alter, having found that it gained ground by every new observation. I have, in particular, observed these forms to prevail exclusively in the valleys of Carlinwork, of Dumfries, and of Kirkcudbright. I imagined, that the diluvian wave had flowed at some remote period from a westerly or north-westerly direction, and had broke over our island; that its magnitude, though perhaps far short of the alpine stream, had been such, that a great body of its water crossing the ridge of country which separates the two coasts, overwhelmed the district in the neighbourhood of this city, discharging itself into the German Ocean. But that another portion of the wave, being retained by that ridge of country, and being left to follow the impulse of gravitation, when the superior water flowed on, had returned again upon the countries which it had just crossed, like the back-draught of a common wave. By watching the operations of a high sea, breaking upon a rapidly shelving beach, covered with coarse gravel, we may form some judgment as to the influence of such a back-draught; the sound produced by the blocks of stone grinding upon each other, as the wave retires, conveys a strong idea of the corrosion which must take place in such circumstances. Our Eastern coast would thus be exposed to a single diluvian action, whereas that on the West would undergo two in succession,

and

and nearly in opposite directions; and the analogy of the events at Lisbon and at Lima, leads us to suppose that several similar actions may have taken place in succession. At Lisbon, five waves in succession followed the first. In the present case, the influence of all but the first, would probably be confined to the western side; or if any of the rest possessed elevation sufficient to surmount the ridge, still the portion of its water which passed over, and that which returned, would each follow the same course with the corresponding portions of the first wave. And there is every reason to believe, that the action would be repeated often upon the side facing the inundation.

The facts seem to correspond with this theory. We have endeavoured to account for the peculiar form of craig and tail, and for the parallel ridges, so frequent on the eastern coast, by the influence of a single powerful stream, the effects of which have since undergone no modification, but from the feeble exertions of diurnal causes; whereas, on the other side of the island, the same set of forms, which we may conceive to have been generated by the first direct impulse, being assailed in new directions, by other forces, less powerful, but frequently repeated, we have reason to expect that these assemblages, composed of loose, and newly deposited materials, would undergo great changes, and that the ridges would be broken down into successions of knolls; that the crags would be filled up, so as to equalise the declivity on all hands; in short, that such a scene as the west coast of Scotland presents to view, would be the result. The circumstances of detail concur with the observations founded on the large features; at least they by no means contradict them. In the west, many striking instances occur, of rocks dressed with grooves and furrows, as already described in the east: but there is this material difference between the

two sets, that whereas in the east, these furrows have preserved the same direction, those on the west follow directions so irregular, as to baffle all arrangement, or, if any such can be traced, it is found to be entirely local, and to depend upon the course of the valleys in the immediate neighbourhood. In some places in the west, as near Moffat, I have met with vestiges of ridges; but, on close inspection, I found them rounded off at both ends. Even these, however, occur but very rarely, and are to be expected, under the hypothesis here laid down, according to which, it is reasonable to suppose, that the effects of the first impulse should not be always completely done away by those which followed. Also the direction of hills in the west, may occasionally have been such as to produce conspiring effects with those of the first action.

In the neighbourhood of the Bay of Kirkcudbright, I have seen two specimens of rock, dressed with furrows, very well characterised, and both indicating a direction from the north; one near the porter's lodge connected with the House of Balmae; the other upon a rock within high water-mark, upon the south side of St Mary's Isle. But the neighbouring country has no corresponding character, all the loose assemblages being arranged in knolls.

On the island in Loch Doon, upon the confines of Ayrshire, and the stewartry of Kirkcudbright, the dressing of the rock is peculiarly interesting. The island is of granite, near its junction with the strata; and the granite contains many sharp angular fragments of killas. Where the rock has undergone the diluvian dressing, the contrast of the two substances is beautifully displayed, the granite being of a light colour, and the killas dark-blue.

By the action of the air, the granite has been decomposed at the surface, and has been corroded nearly to the depth of an inch;

inch; but the killas has resisted that action completely, and its fragments stand above the level of the corroded granite, presenting to view the diluvian dressing unchanged. A curious consequence has resulted from this circumstance: A fine white clay, produced by the decomposition, was mistaken some years ago for marl, and in order to obtain it, a tunnel was cut through the rock, over which the water in its exit to the lake had flowed. The level of the water having in this manner been lowered several feet, a portion of the rock of the island is brought into view, which had previously lain under water, and which, in consequence of the exclusion of air, had not been decomposed, nor had suffered any change, since it underwent the diluvian dressing. The consequence is, that in the upper part of the island, we see the granite corroded, and the killas entire, whereas, near the water's edge, the surface of the rock presents its diluvian dressing throughout; and the two substances are only distinguishable by their colour. We have thus an interesting display of the influence of time; and the circumstance suggests to me a mode, by which the antiquity of these events may perhaps, in a certain degree, be ascertained, and of which some future observer may avail himself. Had the tunnel been cut many centuries ago, at a known period, and had the granite exposed by it to decomposition, undergone a measurable corrosion, we should have been furnished, by instituting a comparison between the two corrosions, with a chronometer, or a rational basis for calculating the antiquity of the diluvian event. The same view may be taken of those blocks of granite in the valley of Monti, upon Saleve, mentioned by SAUSSURE, and alluded to in a former part of this paper.

In the neighbourhood of Loch Doon, a set of very large, loose, and rounded blocks of stone occur, which resemble those

to

to which I have so often alluded in the valley of Geneva: the largest of these is known by the name of the Carnwhaple-stone. The appearance of the country induces me to imagine, that they had been lifted out of the loch by some concentrated force of the returning stream.

A number of large blocks of granite also occur on the hill, at the Pass of Stanmore, in Cumberland, which I was at pains to trace to their source, and found it to be a rock called the Westledale Crag, which is a granite of the same quality with them.

A single block of granite, of four or five feet in diameter, occurs in the street of Darlington.

The transportation of such blocks does not seem to have happened very frequently in Great Britain, at least in those parts of it with which I am acquainted; and where they occur, in the neighbourhood of Edinburgh, they are generally embedded in the blue diluvian clay. That water, however, in the circumstances which we have supposed, does possess the power of transporting very large blocks, we learn by a direct proof, in what was done at Cadiz by the wave which accompanied the earthquake in 1755. It broke down a large piece of the rampart, and carried solid masses of masonry, of eight or ten tons weight, to the distance of forty or fifty yards, as we learn by the account of Mr B. Bewick, (*Philosophical Transactions*, vol. xlix.)

THE observations I have made on this diluvian subject, has been confined to a small range of country, comprehended between our two seas, because it is only of that small range that I can speak with any tolerable certainty; but I have reason to believe, that other members of this Society, possessed of every requisite advantage, are ready to take up this curious subject, and to pursue it with vigour. On that account, I have the less scruple in bringing forward views, that may to many appear extravagant, since there is reason to expect, that whatever errors I may have committed will soon be rectified.

I trust also, that the facts brought forward in this paper, are susceptible of an extensive application, and that they furnish the means of ascertaining the direction of diluvian inundations across the great continents. By a comparison of directions, these tremendous agents may be traced to their source. The native place of the granite blocks, mentioned in the 1st part of this paper as occurring on the shores of the Baltic, and also of those on Mount Jura, may thus be discovered. If both sets came from Mont Blanc, we may expect to find between it and the Baltic Sea a system of crag and tail like that in the neighbourhood of Edinburgh. If the Prussian blocks came from another quarter, the circumstance will soon speak for itself, and the question will probably be decided by the first traveller acquainted with these ideas, who passes, ever so rapidly, through those countries.

In the same manner, we may expect to see light thrown on the history and circumstances of that tremendous event already

dy alluded to, as indicated by the observations of PALLAS; by which it appears that the skeletons, and even carcases of great animals and fish, natives of the torrid zone, are found embedded in the soil along the banks of the great Russian rivers, and buried in the earth, in the frozen regions along the shores of the North Seas, where thaw never penetrates more than a yard below the surface.

The series of inquiries, the result of which I have laid before the Society in the course of this season, was first suggested to me by the vertical rents, filled with congealed lava, which are visible on the craggy face of Somma, the ancient part of Mount Vesuvius. They exhibit a clear view of those restraints under which the eruptive efforts of volcanoes are held in quiet times, and which are occasionally surmounted; and this circumstance, transferred by analogy to the plutonic regions, has afforded, by means of the forcible intrusion of liquid granite, a satisfactory account of the convoluted structure of the strata of killas, when in a semifluid and flexible state; the convolutions thus formed, furnishing an easy explanation of vertical stratification.

The same restraint, occasionally overcome, has explained the protrusion of whinstone among the secondary strata, sometimes in vast beds parallel to them, and sometimes in huge amorphous masses. The restraint exerted by these inflexible obstacles, being surmountable only by acts of violence, I have concluded that the elevations, both volcanic and plutonic, must have been accompanied by a succession of powerful starts; and great part of these operations taking place under the sea, that enormous waves must have been thus produced. In this manner, a satisfactory account has been furnished of earthquakes, and of their attendant waves, as well as of the overwhelming inundations alluded to in this paper, the reality

of

of which is evinced, as has been shewn, by the concurrence of a three-fold set of facts, surrounding us in this neighbourhood. 1. The distribution of loose matters in tails and ridges, on this side of the Island, and in knolls on the West. 2. The grooves and scoopings, and obtuse-angled ridges, occurring on the surface of rocks of every description; and, lastly, the scratches and other minute features of abrasion, which are found to accompany the large features, where the rock has been protected from injury. All these events have been shewn to arise, as natural consequences, out of the Huttonian Theory.

As another consequence of these events, I have also brought forward the formation of valleys of all sorts. I have imputed the detachment of mountains, and the formation of islands, as well as of promontories and arms of the sea, to circumstances which could not fail to take place in the forcible elevation of stiff and frangible masses, performed by a succession of local efforts from beneath, urged by irresistible power *.

I have furnished a theory of the formation of lakes, which does not seem hitherto to have been accomplished in a satisfactory manner, by any other hypothesis. One class, belonging

* Since the first part of this paper was printed, a very familiar circumstance has presented itself, which affords a clear illustration of this great natural operation. When a mason is preparing common lime for building, he lays the burnt limestone in a heap, and throws water upon it; after this, some time elapses before any action is visible, before the lime, as it is said, begins to fall; in this interval the sand, which is to be mixed with the lime, is thrown upon the heap, so as to cover it completely, and the surface is made smooth and uniform by repeated blows of the flat of a spade. Soon after this, a heave takes place from within; the lime swelling, raises up the sand, and divides it by numberless rents, which becoming wider and wider upwards, as the heave advances, a representation in miniature is produced, of an alpine district.

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ing to solid rocks, I have derived from rents formed by inequalities of elevation, and the opening of rents upwards. Another class, formed in alluvial districts, has been traced to modifications performed by various obstacles upon the depositions made by the great inundations alluded to.

In thus controverting some of the collateral opinions of Dr HUTTON and Mr PLAYFAIR, I venture to hope that my arguments, which have been founded on their principles, and which have led me to acquiesce in their most general and important conclusions, may tend less to weaken, than to confirm, the result of their immortal labours.

SPECIMENS.

SPECIMENS.

No. 1.	Craigleith Quarry, from -	W. 5° S. to E. 5° N.
2.	Maiden Craig, - -	W. 5° S.
3.	Ravelstone old farm-yard, -	W. due.
4.	Well Craig, near Craigcrook,	W. 20° S.
5.	Craighouse Quarry, -	W. 5° S.
6.	North of ruin at Dean of North Clermiston, - - -	W. 10° S.
7.	North-east of cottages there,	W. 10° S.
8.	Middle of the North Hill Park,	W. 10° S.
9.	South side of ditto, -	W. 10° S.
10.	Bare space west of summit,	W. 10° S.
11.	Summit of the hill, - -	W. 10° S.
12.	South-east corner of South Mid-Hill Park, -	W. 15° S.
13.	Summer-house on second summit, belonging to Ravelstone,	W. 15° S.
14.	Sheep Park of Corstorphine Hill House, -	W. 8° S.
15.	Below Murrayfield Quarry, east of Belmont, -	W. 15° S.
16.	Dickson's Craig, Barnbugle,	W. 3° S.
17.	Redhall, - - -	W. 8° S.
18.	Ravelrig, - -	W. 15° S.
19.	Kingston, near North Berwick,	W. 15° S.

LIBRARY OF THE BOMBAY BRANCH OF THE ROYAL ASIATIC SOCIETY

Fig 1.

Fig 2.

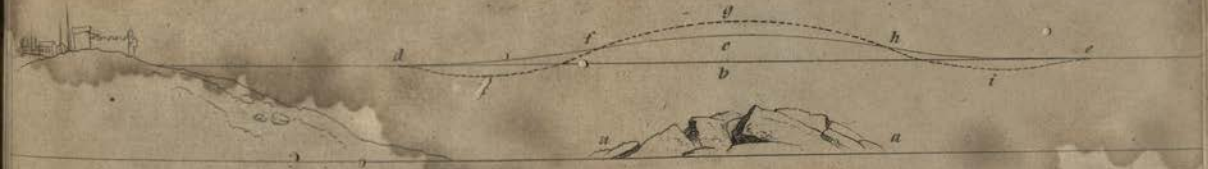

Fig 3.

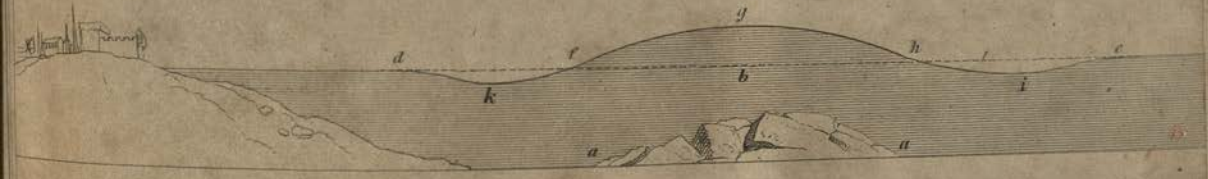

Fig 4.

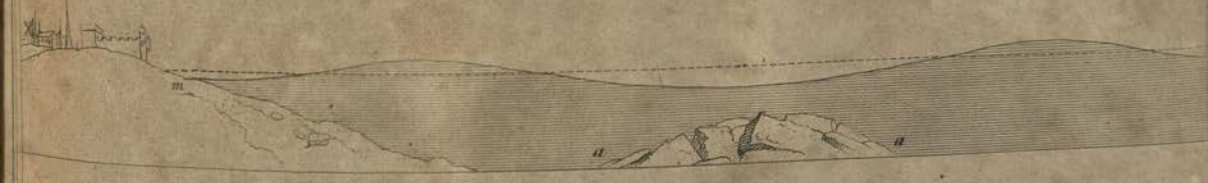

Fig 5.

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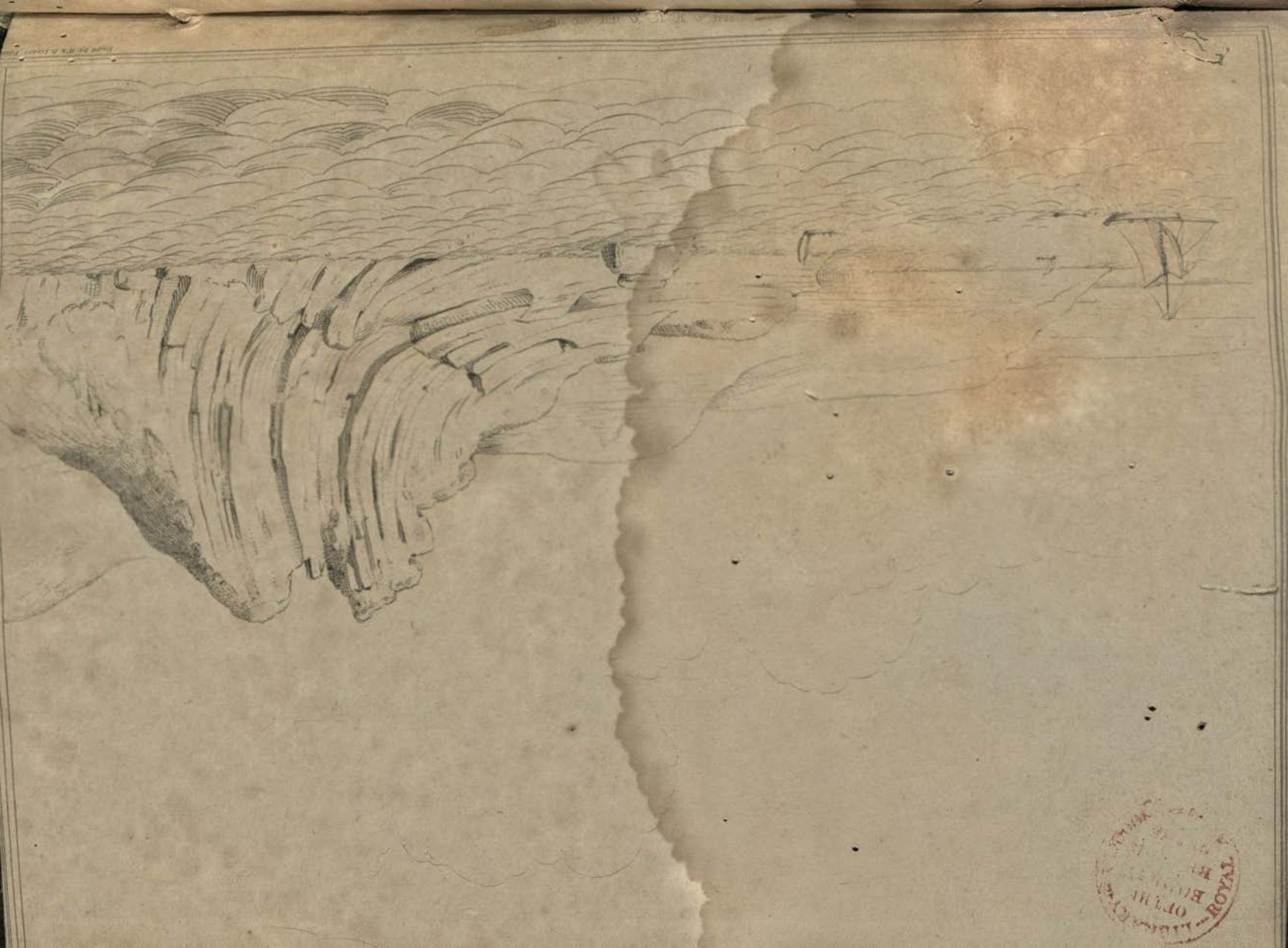
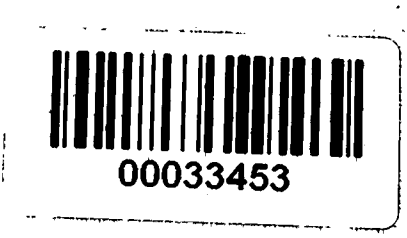


Road to Leith
Old Barnton house
Pirniefield
3 to Leith
Mains
Krew
MUTTONHOLE
East Drylaw
Drylaw
Hill house
Marchfield
4 to Edin.
Queensferry Road
Craighouse Quarry
Groathill
Glen of N. Clermiston
Maiden Craig
Comely bank
Craigleith Quarry
Cottage in ruin
Blinkbonny
Craigcrook Castle
Signal Post
Ravelston
Deanpark
Dean
Mid Clermiston
South Midhill Park
Ravelston Farm Offices
Clermiston
Stone View
South Hill Park
1 Mile
Murrayfield
Belmount
Sheep Park
1 to Edinburgh Toll
Corstorphine hill house
Beechwood
Cattlebridge
2 to Edin.
Glasgow Road
Main
Stank
CORSTORPHINE
PLAN
of
CORSTORPHINE H
&
VICINITY
Surveyed by James Flin
EDINBURGH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